SUSTAINABILITY & SPORTS SCIENCE JOURNAL

ORIGINAL ARTICLE

The functional rehabilitation of ankle trauma by the graduate in motor science: Experimental study

Maria Chiara Parisi . *Department of Medicine and Surgery. University of Enna Kore. Enna, Italy.*
Alberto Canzone. *Graduated in Sports and Physical Activity Sciences. University of Enna Kore. Enna, Italy.*
Omar Mingrino. *Department of Human and Social Sciences. University of Enna Kore. Enna, Italy.*
Vincenzo Cristian Francavilla. *Department of Human and Social Sciences and Department of Medicine and Surgery. University of Enna Kore. Enna, Italy.*

ABSTRACT

Sports trauma commonly affects joints of the extremities; ankle injuries are one of the most common. The study aimed to rehabilitate ankle trauma with proprioceptive exercise, performed, by graduate in motor science. Trauma causes joint instability, which is manifested mainly in running and walking. For this reason, baropodometry and motor tests were used as evaluation criteria; evaluating joint instability in both static and dynamic and neuromotor abilities. Seven athletes (aged 17 and 24 years old) are recruited for the study; they had suffered ankle trauma. The rehabilitation program involved the supervision of a multidisciplinary team (neurologist, posturologist, kinesiologist, sports doctor, observers). Each treatment was always at the same time and included 3 phases: the first on specific work to recover joint mobility, in the second the work was focused on recovering strength, third phase was aimed at recovering ankle sprains. The athletes were administered proprioceptive functional rehabilitation programs aimed at recovering the ankle trauma and plantar pressures. The data were positive and encouraging with respect to the planned goal, supporting the importance of proprioception and the role of the graduate in motor science in the functional re- education of trauma.

Keywords: Health, Ankle trauma, Athletes, Rehab.

Cite this article as:
Parisi, M. C., Canzone, A., Mingrino, O., & Francavilla, V. C. (2023). The functional rehabilitation of ankle trauma by the graduate in motor science: Experimental study. *Sustainability and Sports Science Journal*, *1*(2), 98-114. https://doi.org/10.61486/MLEK9455

Corresponding author. *Department of Medicine and Surgery and Department of Human and Social Sciences, Kore University, 94100 Enna, Italy.*
E-mail: mariachiara.parisi@unikore.it
Submitted for publication August 22, 2023.
Accepted for publication September 05, 2023.
Published October 27, 2023.
Sustainability and Sports Science Journal. ISSN 2990-2975.

Identifier: https://doi.org/10.61486/MLEK9455

INTRODUCTION

The ankle is a diarthrosis, a type of joint between two bones that allows considerable mobility to two articular heads, located at the distal ends of the tibia and fibula and at the proximal end of the talus. The ankle has the important task of connecting the leg to the foot and thus promoting locomotion movements, maintaining the upright position and the postural system. The ankle is made up of a complex osteo-muscular-ligament system which together give stability to the articulation. Specifically, the ankle ligaments have the task of giving stability to the ankle joint in plantar flexion, dorsiflexion, inversion and eversion movements. In detail, these are the medial or deltoid and lateral ligaments. Despite bearing high compressive and shear forces during gait, the ankle's bony and ligamentous structure enables it to function with a high degree of stability and compared with other joints such as the hip or knee, it appears far less susceptible to degenerative processes unless associated with prior trauma (Brockett et al.,2016).

The complexity of the ankle makes it difficult to understand its instability. (Bonnel et al., 2010) Although in the literature risk factors are classified into intrinsic (bone, ligament and posture) and extrinsic (environment and context).

Mechanical instability is often caused by ligamentous laxity, while functional instability is caused by proprioceptive deficiency. In addition, there are also postural factors such as the varus of the hind feet that promote instability. Understanding the cause of ankle injuries is an essential part of effective injury prevention, but it is so far incomplete.

Nearly 70% of cases of ankle osteoarthritic are secondary to a traumatic event, most frequently involving ankle fractures and subsequently unaddressed chronic ankle instability (Jess et al., 2012). Lateral ankle sprains are one of the most common lower extremity joint injuries and have a high recurrence rate (Van Rijn et al., 2008).

The clinical manifestation is pain and decreased function relating to deficits in strength, range of motion (ROM), and dynamic balance that can last for weeks after injury (Basnett et al., 2013).

The key movement of the ankle joint are plantar and dorsiflexion, occurring in the sagittal plane; ab-/adduction occurring in the transverse plane and inversion-eversion, occurring in the frontal plane (Zwipp et al., 1994). Combinations of these motions create three-dimensional motions called supination and pronation. Both terms define the position of the plantar surface of the foot (Nordin et al., 2001). Motion of the ankle occurs primarily in the sagittal plane, with plantar- and dorsiflexion occurring predominantly at the tibiotalar joint.

The range of ankle movement (ROM) varies between individuals. The movement of the whole ankle in the sagittal plane is between 65 and 70 degrees; the dorsal flexion goes from 10 to 20 degrees, the plantar from 40 to 55 degrees. In daily activities the necessary ROM is very reduced, 30 degrees to walk, 37-56 degrees to go up and down stairs. Ankle dorsiflexion ROM can influence dynamic balance, specifically the anterior reach portion of the Star Excursion Balance Test (SEBT). Mechanical and functional ankle instability can contribute to Chronic Ankle instability (CAI) independently or in combination (Hiller et al., 2011).

Impairments in both static and dynamic balance have been shown to be present in individuals with CAI (De Noronha et al., 2008). These deficits are likely due to altered proprioception and neuromuscular control (Arnold et al., 2009). Moreover, CAI demonstrated significantly less maximum dorsiflexion range of motion on the Weight-Bearing Lunge Test (WBLT) and shorter reach distances on the normalized anterior (ANT) direction of the SEBT (Hoch et al., 2012). The purpose of this study was to determine the relationship between a weight bearing measure of ankle dorsiflexion ROM and SEBT reach distance in the anterior, posterolateral, and posteromedial reach directions as well as the composite SEBT scores in individuals with CAI.

Ankle sprain

The ankle is the articulation most often affected by sprain, both in the sporting context and in the daily activities; other factors that can lead to the sprain are of an intrinsic type, therefore linked to the characteristics of the articulation and proprioception. For example, high ankle mobility and reduced ability to control position and movement of the ankle and foot increase the risk of sprains. Ankle sprains are known to be a frequent occurrence across all sports, accounting for 15% of injuries (Fong et al., 2007).

Furthermore, in many sports, ankle sprains are the most common injury that athletes sustain. The resulting symptoms are acute pain and swelling with possible development of a hematoma, more or less accentuated in relation to the cases, which involve a functional limitation of the district (Hootman et al., 2007). The manifestations are localized in the malleolar and central centre and can extend into the dorsal region of the foot, up to reach the fingers.

The strongest of these structures is the deep portion of the deltoid ligament, the anterior and posterior talo-tibial complex, located at the medial ankle. The ligamentous support on the lateral side is less substantial, and includes the anterior talofibular (ATF), calcaneofibular (CF), and posterior talofibular (PTF) ligaments. Of the two commonly injured lateral ligaments, the ATF and CF, the ATF is the weaker (Siegler et al., 1988). Subjects may also complain of tendinopathies, stiffness, increased muscle volume with instability of the instep with difficulty in walking, this is because the damage of the sprained trauma occurs not only on the ligament that holds the joint stable, but also because nerves, muscles and tendons in the ankle are injured. The contralateral limb is used as a reference.

The common standard for acute care of an ankle injury is known by the acronym P.R.I.C.E.: protection, rest, ice, compression, and elevation (Flegel et al., 2008). The generally accepted period for the acute treatment described below is the first 48 to 72 hours following injury. Protection, in the form of bracing, splinting, or non-weightbearing transport is important to reduce the chance of further trauma to an injured area. Rest from the activity that caused the injury, or similar activities, is war- ranted when a significant potential exists for re-injury or further injury. Applying ice to the injured ankle is helpful for reducing pain, minimizing edema. The treatment and rehabilitation of physically active people trying to return to high level activity requires a proactive and creative approach. In athletes, return of function must be maximized while duration of time away from sport is minimized without introducing unnecessary or unwise risk of re-injury or further injury, either to the ankle or another body region. The rehabilitation and rehabilitation phase in the injury of the ankle in the athlete is of fundamental importance to help the latter to return to the field in an optimal way and without relapses. In the field of ankle re-education we can talk about "*proprioceptive re-education*".

that is, all those methods and exercises aimed at stimulating and re-educating the proprioception, that is the ability to know, even with closed eyes, the position of our body in space. We recall that particular receptors collect input of peripheral origin and transmit them to the SNC that processes the information received and integrates them with other affiliations to organize motor responses. The function of the proprioceptors is therefore important for muscle tone, posture and movement. Proprioception exercises are specific exercises that stimulate the proprioceptive system, to train it to provide quick and adequate responses in destabilizing and dangerous situations, with the aim of making the individual better understand his own body. As for the ankle, proprioceptive re-education must aim to acquire greater coordination in the articulation muscle contractions and bone levers, in accordance with the movement. Initially the re-education is carried out in a passive way, to accustom the athlete to perceive different characteristics of the movement induced and making him aware of his motor possibilities. Then we will work to recover a correct distribution of the load. Exercises develop on unstable surfaces, such as semispheres or square tablets. The athlete must learn to maintain balance with simple movements of the ankle, first with open eyes with our help, and then without help and visual control. It continues working in monopodalica both on the injured ankle and on the healthy one. When the athlete has recovered a good walking, we proceed with the development of a proprioceptive path composed of cushions that have a different consistency and deformity, to adapt the pace and stimulate the proprioceptive receptors during the walk on a non-homogeneous ground.

In the re-education and in the motor reactivation post distortive trauma is fundamental the muscular reinforcement, because a good trophism of the muscles reduces the risk of relapses and allows the athlete to resume the sporting activity. In the re-education of the ankle after a sprained trauma, we must pay attention to the movements that we will do to the athlete because they could again damage the ankle injured by the trauma. So, it is advisable to begin with light exercises, divided into several sets with a few repetitions.

Growing evidence supports the use of exercise therapy as the main component of the treatment program (Kerkhoffs et al., 2012) (Bleakley et al., 2010). The efficacy of exercise therapy programs has been established, especially when initiated early following an acute ankle sprain (Vuurberg et al., 2018) (Van Rijn et al., 2009).

MATERIALS AND METHODS

Seven athletes (Table 1) aged between 17 and 24 years were recruited for the study. Inclusion criteria were: absence of neurological deficits, absence of vestibular disorders, presence of functional ankle deficits, presence of ankle deficits caused by sprain, being an athlete. Exclusion criteria consisted of currently participating in a structured post-injury ankle recovery exercise programme. All participants was recruited after an examination by the sports and orthopaedic physician. All athletes received a full explanation of the protocols prior to the start of the study and signed an informed consent form for the tests and motor protocol.

Table 1. Participants.

Case	Age	Gender	Height
1	24	M	191 cm
2	22	F	163 cm
3	26	F	170 cm
4	18	M	180 cm
5	19	F	168 cm
6	20	M	184 cm
7	17	M	170 cm

Procedures

The experimental group (n = 7) performed the training using functional re-education protocols, under the supervision of the same investigator (kinesiologist and posturologist) and at the same time of day (between 18:00 and 19:30). The protocols were programmed both in relation to the condition of the athlete himself, and in relation to the specific injury for which it is necessary to recover all joint and motor functions. It was structured in 3 phases: the first ~~phase~~ on specific work to recover joint mobility, in the second phase the work was focused on recovering strength, and the third phase was aimed at recovering ankle sprains. An incorrect re-educational programme results in a very high incidence of new injuries. Functional re-education plays a key role in this.

Methodology

The method of investigation used to analyse the various samples examined is the Baropodometric examination, a technique that can measure, point by point, the pressures exerted by the foot on the ground. The baropodometric platform is an instrument for measuring foot support that gives us the opportunity to evaluate the subjects while keeping their point of view unchanged. As for the intervention protocol for the re-education the method used is the proprioceptive exercise on particular carpets called "*SINERGY MAT*". (Figure 1) Proprioception is an important mechanism in stability and function (Boerboom et al., 2008).

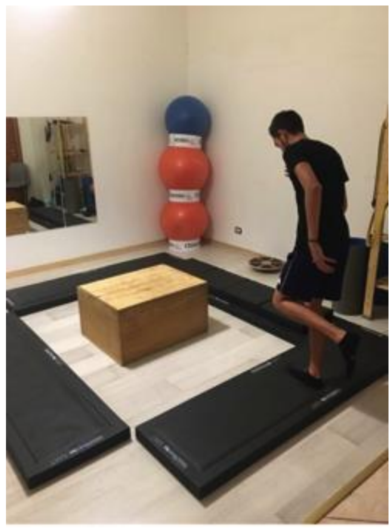

Figure 1. Sinergy Mat.

Human Tecar Synergy Mat consists of a series of platforms that simulate different terrain at different levels of instability. It allows to stimulate the muscles especially the one suitable for stabilization, avoiding the impact on the joint surfaces as happens on rigid soils like a balance training using unstable boards.

Protocol

Exercises included in the motor protocol had the common goal to reduce ankle instability. The entire training was performed for 48 weeks (two sessions per week) for a total of 96 sessions. Each training session consisted of 60 minutes of specific exercises. Specifically:

- Proprioceptive exercises, both static and dynamic.
- Isometric and joint and muscle stabilization exercises.
- Muscle strengthening and strength exercises.
- Stretching exercises.

The aim of this protocol was to stimulate both static and dynamic balance, encourage joint stabilization, restore the receptor system, improve muscular tropism and encourage post-traumatic recovery and thus the resumption of sporting activity. Below, a detailed description of the same.

Step 1: Maintain balance in bipodal support by moving the board vertically and diagonally. Time 20-30 sec. Figure 2.

Figure 2. Step 1.

Step 2: Maintain balance in monopodalic stance on the proprioceptive board. Time 20/30 sec. Figure 3.

Figure 3. Step 2.

Step 3: Maintain balance in bipodal stance by picking up a ball from the ground and holding it in your hands. Time 20/30 sec. Figure 4.

Figure 4. Step 3.

Step 4: Maintain balance in monopodalic stance by picking up a ball from the ground and holding it in your hands. Time 20/30 sec. Figure 5.

Figure 5. Step 4.

Step 5: Maintain balance in monopodalic phase on proprioceptive cushion. Time 20/30 sec. Figure 6.

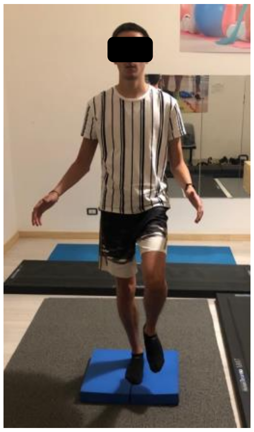

Figure 6. Step 5.

Step 6: bipodal squats on proprioceptive cushion. 3 sets of 10 repetitions. Figure 7.

Figure 7. Step 6.

Step 7: single leg squats on proprioceptive cushion. 3 sets of 10 repetitions. Figure 8.

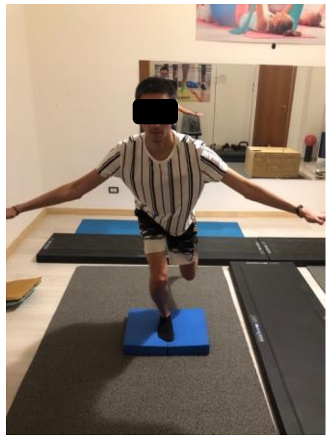

Figure 8. Step 7.

Step 8: alternating course with boards and proprioceptive cushions. They walked the course 5 times. Figure 9.

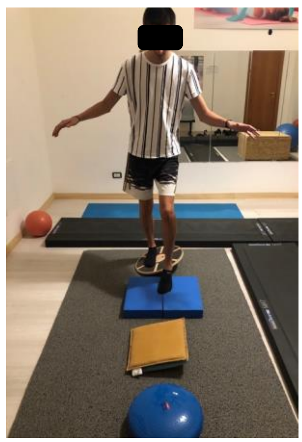

Figure 9. Step 8.

Step 9: low and high Skip on Sinergy Mat for 5/10 min. Figure 10.

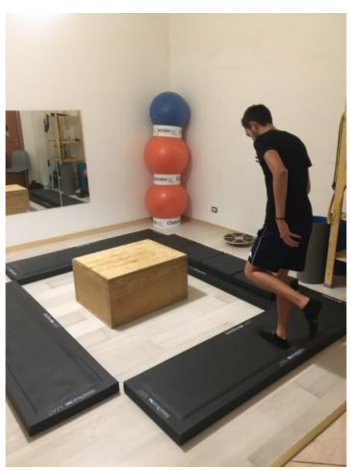

Figure 10. Step 9.

Step 10: Lateral and frontal lunges on Sinergy Mat 3x10. Figure 11.

Figure 11. Step 10.

Step 11: box jump (3x10). Figure 12.

Figure 12. Step 11.

Step 12: Foot thrusts in supination and pronation with small Fitness Ball in counter resistance (3x10). Figure 13.

Figure 13. Step 12.

Step 13: Foot flexion-extension with elastic in counter-resistance (3x10). Figure 14.

Figure 14. Step 13.

Postural balance assessment

Static bipedal stabilometry

Stabilometric parameters were measured using a Freemed baropodometric platform (sensor medica, 00012, Guidonia Montecelio, Rimini, Italy) with the following specifications: platform surface 640 x 740 mm, weight 8.5 kg and thickness 8 mm. The participants were positioned in bipedal mode, with their bare feet side by side on the platform, each foot approximately 20 cm away from the other, without any other type of support. All subjects were oriented to maintain a natural upright position, always looking at a fixed point in front of them for 30.5 seconds with their eyes open. The software obtains the position of the centre of pressure (CoP) load distribution. It also measures the speed of movement of the CoP and the length covered by the CoP. Data were collected and analysed using the software supplied with the platform (FreeStep), which continuously records CoP trajectories at a sampling rate of 100 Hz.

Gait analysis

For the initial and final gait evaluation was used "*Gait analysis*". Using sophisticated instrumentation, it was possible to measure foot and ankle movements and mechanics in relation to the body and the activity of the musculoskeletal systems (Levine et al., 2012). Gait analysis is used to assess and treat individuals with conditions affecting their ability to walk. It is also commonly used in sports biomechanics to help athletes run more efficiently and to identify posture-related or movement-related problems in people with injuries. The pioneers of scientific gait analysis were Aristotle in De Motu Animalium (Aristotle, 2004). The most recent scientists were Giovanni Alfonso and Borelli in 1600 and Eadweard Muybridge e Etienne Jules Marey in '900.

RESULTS

Report clinical case

Case 1

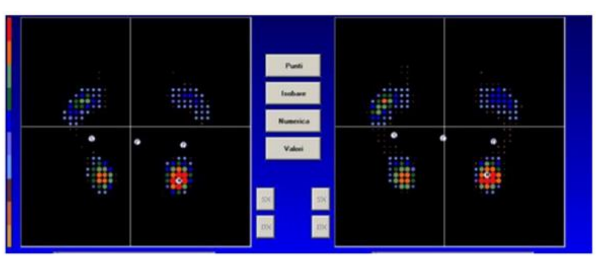

Figure 15. First clinical case before and later.

Table 2. Characteristics of the subject of case 1.

Sex	M
Age	24
Height	1.91 m
Injury	First degree ankle sprain
Sport	Basketball

Subject had a slight ankle sprain due to a change of direction in training and was subjected to a proprioceptive functional re-education plan.

Case 2

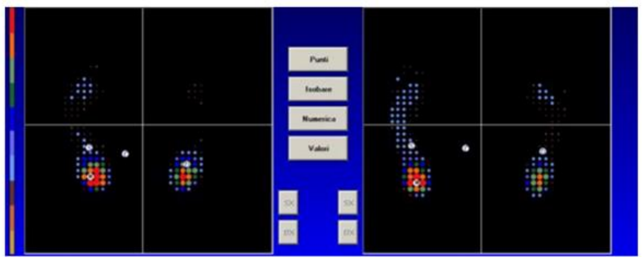

Figure 16. Second clinical case before and later.

Table 3. Characteristics of the subject of case 2.

Sex	F
Age	22
Height	1.63 m
Injury	Second degree ankle sprain
Sport	Fitness

The subject had an injury while warming up at the gym on the tapis and underwent a proprioceptive functional rehabilitation plan.

Case 3

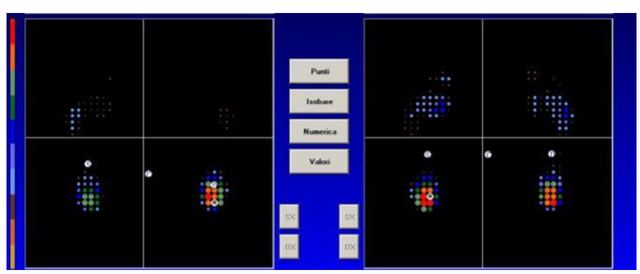

Figure 17. Third clinical case before and later.

Table 4. Characteristics of the subject of case 3.

Sex	F
Age	26
Height	1.70 m
Injury	Second degree ankle sprain
Sport	Dance

The subject, following an exercise on the tips, had a sprained ankle and was subjected to a protocol of proprioceptive functional re-education.

Case 4

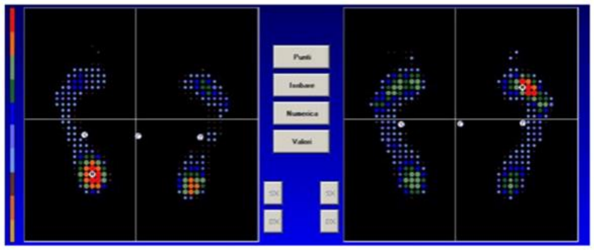

Figure 18. Fourth clinical case before and later.

Table 5. Characteristics of the subject of case 4.

Sex	M
Age	18
Height	1.80 m
Injury	First degree ankle sprain
Sport	Volleyball

Subject injured himself after he'd done the volleyball wall for putting his foot wrong on the ground when he landed. He then underwent a proprioceptive functional rehabilitation protocol.

Case 5

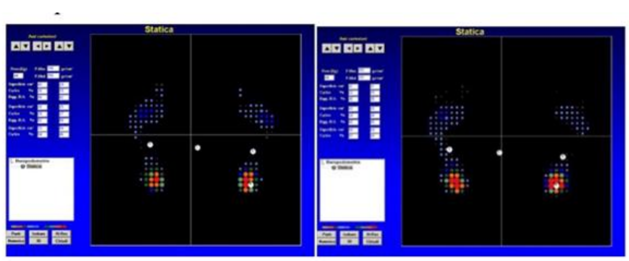

Figure 19. Fifth clinical case before and later.

Table 6. Characteristics of the subject of case 5.

Sex	F
Age	19
Height	1.68 m
Injury	First degree ankle sprain
Sport	Dance

Subject had a slight ankle sprain from a sudden change of direction and underwent proprioceptive functional re-education.

Case 6

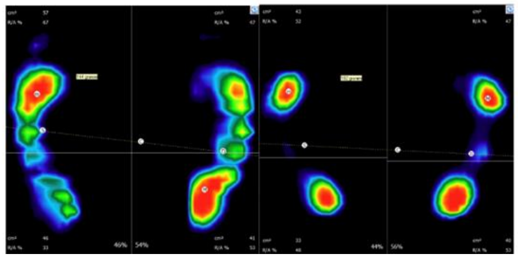

Figure 20. Sixth clinical case before and later.

Table 7. Characteristics of the subject of case 6.

Sex	M
Age	20
Height	1.84 m
Injury	Second degree ankle sprain
Sport	No sport practiced

Subject was injured during a football match and was subjected to a proprioceptive functional rehabilitation protocol.

Case 7

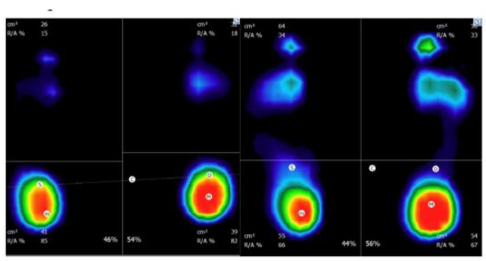

Figure 21. Seventh clinical case before and later.

Table 8. Characteristics of the subject of case 7.

Sex	M
Age	17
Height	1.70 m
Injury	Second degree ankle sprain
Sport	Fitness

The subject was injured playing tennis during a change of direction and was then subjected to a proprioceptive functional re-education protocol.

DISCUSSION

Joint stability is an indispensable component for performing daily activities and for overall physical performance, especially in athletes. Balance training is prescribed to prevent and treat injuries caused by a reduced ability to balance, and part of this training is a series of different plantar support exercises. The aim of this study was to investigate the effects of a specific motor protocol for post-traumatic ankle recovery, conducted by a graduate in exercise science. Hypothesis was partially supported. We do not have absolute certainty that this type of protocol is effective for every case. But the study showed that this 48-week protocol used was associated with a significant improvement in ankle stability, reduced or eliminated pain under load, improved static and dynamic balance compared to baseline, and allowed athletes to return to the field. From the point of view of efficacy, in short- and long-term conditions, previous studies have found an improvement in postural stabilization and balance parameters following 4 weeks of specific sensorimotor training (Aggarwal et al., 2010). Some authors have shown that sensorimotor training is effective in preventing recurrences of ankle sprains, but the pathway through which this effect occurs is unknown. Biomechanical and neurophysiological analyses of sensorimotor training leading to functional changes in the ankle are required to establish this pathway (Hupperets et al., 2009).

The results on joint position sense and muscle reaction times showed a positive effect in both static and dynamic. Measurements taken at T0, taken three months after the start of use of the protocol, and a T1 measurement, taken at the end of the protocol (after 48 weeks) show clear improvements. The results collected in the study, summarised in the concept of variation of breech support and variation of the centre of gravity, are enclosed in the graph.

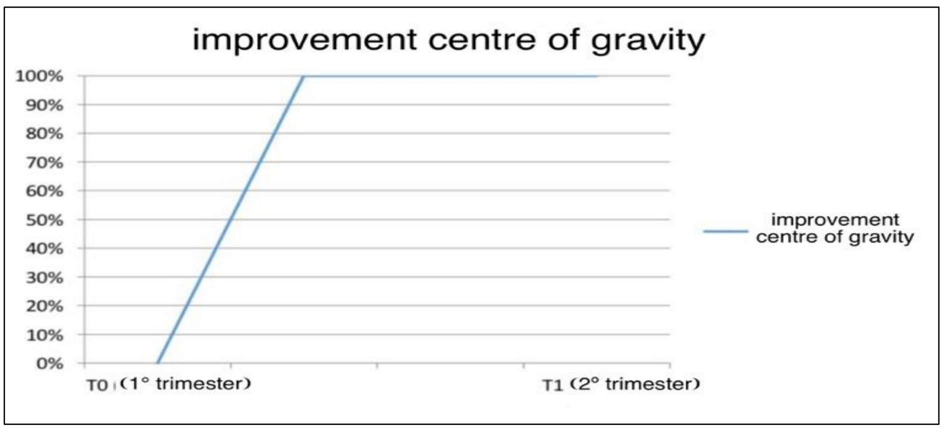

Figure 22. Graph on the change centre of gravity.

No effects on specific muscle strength were found because we did not provide tests to evaluate them. We believe that future studies must overcome our limitations and focus on (i) differentiation between morphological, physiological and functional changes; (ii) larger sample sizes and differentiation of athletes between amateurs and professionals; (iii) use of a longer follow-up period of 48 weeks.

CONCLUSIONS

Improved balance and joint stability of the ankle and the foot-ankle system, can ensure a better post-traumatic recovery of the athlete. The current study showed that only a good, adapted motor protocol, can promote an athlete's post-traumatic ankle sprain recovery. The results suggested that a newly developed protocol based on proprioception, balance and strength, could be an alternative to improve balance and prevent traumatic events in athletes. Furthermore, this type of programme, could be recommended to be included in the pre-competition training routine. In an injured athlete, a timely and safe return to training or competition is the desired outcome of the recovery process.

AUTHOR CONTRIBUTIONS

Conceptualization, M. C. P., O. M.; writing original draft M. C. P., O. M.; writing revision and editing: M. C. P.; visualization and supervision: V. C. F.; project design: M. C. P.; investigation, A. C., O. M.; data curation: O. M. All authors read and approved the final edited manuscript. All authors reviewed and approved the final manuscript.

SUPPORTING AGENCIES

No funding agencies were reported by the authors.

DISCLOSURE STATEMENT

No potential conflict of interest were reported by the authors.

ETHICAL PUBLICATION STATEMENT

We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

INSTITUTIONAL REVIEW BOARD STATEMENT

The study was conducted in accordance with the Declaration of Helsinki, and approved by Ethics Committee University Kore of Enna, for studies in-volving humans.

INFORMED CONSENT STATEMENT

Informed consent was obtained from all subjects involved in the study Written informed consent for publication must be obtained from participating patients who can be identified. Written informed consent has been obtained from the patient(s) to publish this paper if applicable.

ACKNOWLEDGMENTS

The authors thank all persons who participated in the study and the entire multidisciplinary team who created the protocol.

REFERENCES

Aggarwal, A., Zutshi, K., Munjal, J., Kumar, S., Sharma, V. (2010) Comparing stabilization training with balance training in recreationally active individuals. Int J Ther Rehabil., 17, 244-253. https://doi.org/10.12968/ijtr.2010.17.5.47843

Aristotle. (2004) On the Gait of Animals. Kessinger Publishing, 978-1-4191-3867-6.

Arnold B.L., De La Motte S., Linens S., Ross S.E. (2009). Ankle instability is associated with balance impairments: A meta-analysis. Med Sci Sports Exerc., 41(5):1048-1062. https://doi.org/10.1249/MSS.0b013e318192d044

Basnett, C. R., Hanish, M. J., Wheeler, T. J., Miriovsky, D. J., Danielson, E. L., Barr, J. B., & Grindstaff, T. L. (2013). An-kle dorsiflexion range of motion influences dynamic balance in individuals with chronic ankle instabil-ity. International journal of sports physical therapy, 8(2), 121-128.

Bleakley C.M., O'Connor S.R., Tully M.A., Rocke L.G., Macauley D.C., Bradbury I., Keegan S., McDonough S.M. (2010) Effect of accelerated rehabilitation on function after ankle sprain: randomised controlled trial. BMJ.; 340:c1964. https://doi.org/10.1136/bmj.c1964

Boerboom, A. L., Huizinga, M. R., Kaan, W. A., Stewart, R. E., Hof, A. L., Bulstra, S. K., & Diercks, R. L. (2008) Valida-tion of a method to measure the proprioception of the knee. Gait & Posture, 28(4), 610-614. https://doi.org/10.1016/j.gaitpost.2008.04.007

Bonnel, F; Toullec, E., Mabit, C., & Tourné, Y. (2010). Chronic ankle instability: biomechanics and pathomechanics of ligaments injury and associated lesions. Orthopaedics & traumatology: Surgery & research, 96(4), 424-432. https://doi.org/10.1016/j.otsr.2010.04.003

Brockett, C. L., & Chapman, G. J. (2016). Biomechanics of the ankle. Orthopaedics and trauma, 30(3), 232-238. https://doi.org/10.1016/j.mporth.2016.04.015

De Noronha M., Refshauge K.M., Crosbie J., Kilbreath S.L. (2008). Relationship between functional ankle instability and postural control. J Orthop Sports Phys Ther., 38(12):782-789. https://doi.org/10.2519/jospt.2008.2766

Flegel M.J. (2008) Sport First Aid (4th ed). Champaign, IL: Human Kinetics.

Fong D.T.P, Hong Y., Chan L.K., et al. (2007) A systematic review on ankle injury and ankle sprain in sports. Sports Med.; 37(1):73-94. https://doi.org/10.2165/00007256-200737010-00006

Hiller C.E., Kilbreath, S.L., Refshauge K.M. (2011). Chronic ankle instability: Evolution of the model. J Athl Train., 46(2):133-141. https://doi.org/10.4085/1062-6050-46.2.133

Hoch, M. C., Staton, G. S., McKeon, J. M. M., Mattacola, C. G., & McKeon, P. O. (2012) Dorsiflexion and dynamic pos-tural control deficits are present in those with chronic ankle instability. Journal of Science and Medicine in Sport, 15(6), 574-579. https://doi.org/10.1016/j.jsams.2012.02.009

Hootman J.M., Dick R., Agel J. (2007) Epidemiology of collegiate injuries for 15 sports: summary and recommenda-tions for injury prevention initiatives. J Athl Train.; 42(2):311-9.

Hupperets, M.D.W., Verhagen, E.A.L.M. & van Mechelen, W. (2009) Effect of Sensorimotor Training on Morphologi-cal, Neurophysiological and Functional Characteristics of the Ankle. Sports Med 39, 591-605. https://doi.org/10.2165/00007256-200939070-00005

Kerkhoffs G.M., Van Den Bekerom M., Elders L.A., Van Beek P.A., Hullegie W.A., Bloemers G.M., De Heus E.M., Loogman M.C., Rosenbrand K.C., Kuipers T., et al. (2012) Diagnosis, treatment and prevention of ankle sprains: an evidence-based clinical guideline. Br J Sports Med.; 46:854-860. https://doi.org/10.1136/bjsports-2011-090490

Levine D., Richards J., Whittle M. (2012) Whittle's Gait Analysis. Elsevier Health Sciences, ISBN 978-0702042652.

Nordin, M., & Frankel, V. H. (2011). Basic biomechanics of the musculoskeletal system. Lippincott Williams & Wilkins.

Siegler S., Block J., Schneck C.D. (1988) The mechanical characteristics of the collateral ligaments of the human ankle joint. Foot Ankle; 8(5):234-42. https://doi.org/10.1177/107110078800800502

Snedeker, J. E., Wirth, S. H., & Espinosa, N. (2012). Biomechanics of the Normal and Arthritic Ankle Joint, Foot and Ankle Clinics, Volume 17, Issue 4, 517-528. https://doi.org/10.1016/j.fcl.2012.08.001

Van Rijn R.M., Van Heest J.A., Van Der Wees P., Koes B.W., Bierma-Zeinstra S.M. (2009) Some benefit from physio-therapy intervention in the subgroup of patients with severe ankle sprain as determined by the ankle function score: a randomised trial. Aust J Physiother.; 55:107-113. https://doi.org/10.1016/S0004-9514(09)70040-6

Van Rijn, R.M., Van Os, A.G., Bernsen, R.M.D., Luijsterburg, P.A., Koes, B.W., & Bierma-Zeinstra S.M. (2008) What is the clinical course of acute ankle sprains? A systematic literature review. The American journal of medicine, 121(4), 324-331.e6. https://doi.org/10.1016/j.amjmed.2007.11.018

Vuurberg G., Hoorntje A., Wink L.M., Van Der Doelen B.F.W., Van Den Bekerom M.P., et al. (2018) Diagnosis, treat-ment and prevention of ankle sprains: update of an evidence-based clinical guideline. Br J Sports Med.; 52:956. https://doi.org/10.1136/bjsports-2017-098106

Zwipp, H., & Randt, T. Ankle joint biomechanics. (1994) Foot and Ankle Surgery, 1(1), 21-27. https://doi.org/10.1016/S1268-7731(05)80052-9