PROPRIOCEPTIVE TRAINING IN THE COMPLEX FUNCTIONAL RECOVERY AFTER LATERAL ANKLE SPRAIN

Lyubomira Sazdova
National Sports Academy "Vassil Levski", Sofia, Department of "Theory and methods of kinesitherapy", Bulgaria, l_sazdova@abv.bg

Abstract: The lateral ankle sprain is one of the most common injuries, especially in competitive sports and recreational activities, and often leads to residual symptoms, such as pain, subjective instability, loss of function, repetitive injury and risk of developing chronic ankle instability. One of the most effective methods of improving the dynamic stabilization and the complex function of the ankle is proprioceptive training. The aim of this report is to present a physiotherapeutic program for functional recovery, with an emphasis on proprioception and balance training, and to evaluate its effectiveness on static and dynamic postural control in patients with lateral ankle sprain. Material and methods: Nine patients (mean age 25,6 years) with grade II lateral ankle sprain, treated non-operatively participated in the study. The specialized physiotherapeutic program included exercises and techniques for reactivation of the fibular muscles, and balance and proprioceptive training, performed on unstable surfaces. The progression was made by moving from non-weight-bearing to weight-bearing position, and by decreasing the base of support from bilateral to unilateral stance on the affected lower limb. Patients were challenged by incorporating trunk perturbations, head, upper and lower extremity movements, as well as functional activities, performed on unstable surfaces. The functional outcome and static and dynamic postural balance control were assessed using static (One-leg stance) and dynamic (Y balance test) balance tests. Results: The baseline One leg stance and Y balance test measures of our patients showed in general diminished static balance and impaired dynamic postural control. The results of the last follow up after 8 weeks of proprioceptive training showed a statistically significant improvement in all the investigated indicators, but a presence of a certain deficit was found in the assessment of both static and dynamic stabilization. In order to achieve optimal functional results, the implementation of specialized proprioceptive training should continue until the functional deficit is completely overcome. Conclusion: Early inclusion of a specialized individualized physiotherapy and training of the proprioception and dynamic stabilization could successfully reduce the deficit in neuromuscular control and static and dynamic balance. The proprioceptive training should start as early as possible, should be individualized according to functional limitations and arthrokinematic changes of the whole kinetic chain of the injured lower limb and patients' capabilities, and designed to provide successful return to previous functional level of activity and participation in recreational and sports activities.
Keywords: ankle sprain, physiotherapy, proprioceptive training, balance tests.

1. INTRODUCTION

The lateral ankle sprain (LAS) is one of the most common injuries, especially in competitive sports and recreational activities, and often leads to residual symptoms, such as pain, subjective instability, loss of function, repetitive injury and risk of developing chronic ankle instability. The disruption of the ligaments and other joint connective and soft tissues during the initial trauma, damages the afferent mechanoreceptors, which leads to reduction and alterations in the quality of proprioceptive information (Herb, Hertel, 2014; Röijezon et al., 2015). The decreased kinesthetic awareness and altered neuromuscular activation and proprioception often results in long-term deterioration of postural and balance control, functional instability, alterations in gait and elevated risk of recurrent injury (Han et al., 2015; Punt et al., 2015). Impaired neuromuscular control at time of the injury, muscular imbalance and residual deficit in proprioception may contribute to the development of chronic ankle instability (CAI) (Chen et al., 2019). One of the most effective methods of improving the dynamic stabilization, balance control and and the complex function of the ankle is proprioceptive training.

Proprioception is the one's ability to perceive the joint position and movements, and is a part of the multisystem process of balance and postural control. Sensory signals and information from the proprioceptors regarding body position, musculosekeletal activity, visual feedback, and other inputs provides the nervous system information required for better control of movement (Ferlinic et al., 2019), and for maintaining the balance during daily activities and sport performance (Sefton et al., 2011).

Individuals with ankle instability have deficits in their balance and postural control, and the deficit appear to exist regardless of whether balance is assessed with static or dynamic tests (Arnold et al., 2009). In the literature have shown that patients with LAS and CAI have poor postural control and altered motor neuron strategies (Alghadir et

al., 2020 Aman et al., 2015; Hertel, 2008; Lin et al., 2010; McKeon & Hertel, 2008; Sierra-Guzmán et al., 2018; Wells, 2019).

2. PURPOSE

The study aimed to present a physiotherapeutic program for functional recovery, with an emphasis on proprioception and balance training, and to evaluate its effectiveness on static and dynamic postural control in patients with lateral ankle sprain.

3. MATERIAL AND METHODS

Nine patients (mean age 25.6 years, range 20-39) with grade II lateral ankle sprain (LAS), treated non-operatively participated in the study. All patients meet the inclusion criteria: unilateral LAS, treatment with functional immobilization, no history of previous ankle sprains. Exclusion criteria were: grade III LAS, fractures, systematic diseases, neurological diseases, or any other impairments of the affected lower extremity (history of ACL reconstruction, ets.). All participants were active, but not professional athletes. All subjects provided written informed consent to participate in the study.

The specialized physiotherapy program started as soon as patients tolerated. Once the pain and swelling were controlled exercises and techniques for neuromuscular reactivation and strengthening of the fibular muscles were included. To avoid uncontrolled and painful movements of the ankle resistive exercises started with dynamic isometrics with Therabands. When the patients demonstrated good movement control resistive isotonic exercises were added. Regardless the emphasis in training was on fibular muscles, because of the inversion mechanism of the injury, to develop better control and dynamic stabilization all ankle muscles were trained, with accent on the eccentric phase of the exercises.

The proprioceptive program was included as early as possible, and its application was tailored to the type of trauma, the degree of damage and the regeneration process of the affected ligaments and soft tissues. Although following general rules of progression, summarized by Bellows & Wong (2018), proprioceptive training was individualized for each patient as progress was not only determined by time frames, but also by participants' functional capabilities to maintain good balance and postural control during exercises.

Proprioceptive training started from non-weight bearing position, with exercises for kinesthetic - joint position and movement sense. To activate postural mechanisms, exercises on soft and unstable surfaces (such as Gym ball, stability Theraband trainers, foam steps, balance air pads, and balance boards, etc.) were used. At first exercises were performed from non-weight bearing position (sitting on a Gym ball) and gradually progressed to weight bearing (standing) position. From these positions body perturbations and head, trunk, upper and lower limbs movements were included, and the goal of each exercise was to be performed with appropriate postural stabilization. To challenge the patients resistive exercises with Therabands were added, and the vector and degree of the resistance being selected according to the patients' capabilities. The exercises progressed by decreasing the base of support from bilateral to unilateral stance on the affected lower limb (as soon as ankle was pain free with loading), and from full foot support to toe support (where the ankle is in a position of joint relaxation/ less stable position, in which the dynamic stabilization is of great importance). To add additional difficulty and to challenge the patients all exercises were performed on unstable surfaces with different grade of instability. Initially all exercises were implemented in front of a mirror for better visual feedback and gradually the visual control was limited by performing exercises without a mirror. To challenge the proprioception and balance control, visual system was excluded by performing the exercises with eyes closed.

Once the patients demonstrated good static and dynamic balance, proprioceptive training progressed by incorporating functional activities and sport specific tasks – forward and lateral lunges, mini squats, steps up/ down, walking with change the directions. All exercises were performed on soft or unstable surfaces with both affected and unaffected lower limbs, and for additional difficulty Theraband resistance on lower limbs was added. Walking forward, sideways and backward on proprioceptive paths with steps with different size and degree of stability was also included. Simple plyometric exercises and running drills training started at the end of the training program in some patients, if no symptoms were provoked and if patients demonstrated good balance and dynamic stabilization of the ankle, but more demanding functional exercises were postponed until after full healing has taken place. To obtain good neuro-muscular control, sufficient to practice sport activities, more prolonged and sport specific proprioceptive training is needed.

The participants performed the proprioceptive program 4-5 times per week with duration 35-45 min.

To assess the effect of the proprioceptive training program and the static and dynamic postural balance One-leg stance (OLS) test and Y-balance test (YBT) were used.

To evaluate static balance (OLS), the participants were asked to stand on one leg, hands resting at the waist level. The test was performed with eyes closed. OLS duration was measured in seconds (sec), and 30 sec was accepted as a norm.

The Y balance test (shortened version of the Star Excursion Balance Test) was used for assessment of the dynamic postural balance abilities. While maintaining single leg stance, the subject was asked to reach with the free limb in the anterior, posteromedial, and posterolateral directions, in relation to the stance foot. The greatest successful reach distance (cm) for each direction was used for analysis of the reach distance in each direction (Pliski et al, 2009).

All patients were tested on the 1st month and after 8 weeks of proprioceptive training. Means and standard deviations were calculated for each of the investigated indicators. A dependent-sample *t*-test was used to determine if there was a difference between initial and post-training results, and the significance level was considered at $\alpha<.05$.

4. RESULTS

The baseline OLS and YBT measures of our patients showed in general diminished static balance and impaired dynamic postural control.

The statistical results of OLS are presented in Table 1. The data of the initial examination of OLS test demonstrated difficulties in maintaining the equilibrium, with relatively low values and mean score for the injured lower limb of 8.12±2.44 sec. After 8 weeks of supervised specialized proprioceptive training statistically significant improvement ($\alpha<.001$) was established, and the result reached mean value of 21.06±5.57 sec. (Table 1). Despite the improvements, the results do not reach those of healthy individuals and the norm of 30 sec.

Table 1. Statistical results of One Leg Stance Test of the affected lower limb.

	4 week		12 week		ΔX	*t*	α
	$\bar{x}$	*S*	$\bar{x}$	*S*			
OLS	8.12	2.44	21.06	5.57	12.94	8.77	α<.001

Legend: $\bar{x}$ - mean value in sec.; *S* – standard deviation; ΔX – mean difference; *t* – Student's t-test ; α – significance level.

Statistically meaningful improvement and strong effect size ($\alpha<.001$) was also found in the dynamic balance assessment of our patients, confirmed by the improvement of all three reach distances of YBT. The lowest initial results were found in the anterior reach, where the average value before the proprioceptive training was 49.87±4.95 cm, and the highest mean score was found in posteromedial direction – 62.77±3.56 cm. The data from the first examination of the reach distance in posterolateral direction showed mean score of 59.7±3.21 cm.

Table 2. Statistical results of Y-Balance test of the affected lower limb.

YBT Reach distance	4 week		12 week		ΔX	*t*	α
	$\bar{x}$	*S*	$\bar{x}$	*S*			
Anterior	49.87	4.95	57.81	4.77	7.94	5.43	α<.001
Posteromedial	62.77	3.56	71.13	4.48	8.36	4.39	α<.001
Posterolateral	59.7	3.21	67.42	3.79	7.72	4.43	α<.001

Legend: $\bar{x}$ - mean value in cm; *S* – standard deviation; ΔX – mean difference; *t* – Student's t-test ; α – significance level.

At the last follow-up, after 8 weeks of proprioceptive practicing, the highest increase was found in the posteromedial direction (d=8.36), and the sequence of the results was the same, with the highest average value in posteromedial direction (71.13±4.48), followed by posterolateral (67.42±3.79) and anterior direction (57.81±4.77).

5. DISCUSSION

The initial examination of OLS and YBT of our patients confirm the statement that postural impairments are present in individuals with LAS. Poor results were mostly associated with impairment of the mechanoreceptors during the time of the injury, the feeling of instability, and presence of slight discomfort with weight bearing in single leg stance in some of the patients. After 8 weeks proprioceptive training a statistically significant improvement was found in both static and dynamic postural control tests.

Literature shows that balance training is an effective modality in the rehabilitation and prevention of recurrent sprain in patients with acute ankle sprain and CAI, and could be used as prophylaxis in sports practice.

The findings of a systematic review and meta-analysis of Bellows et al (2018) support the use of bracing and balance training to reduce the incidence and relative risk of ankle sprains in athletic populations, with or without a

prior sprain compared to no-treatment controls. Other systematic reviews showed that prophylactic balance and coordination training substantially reduce the risk of ankle sprain injuries in athletes, with a greater effect seen in those with a history of sprain (McKeon & Hertel, 2008; Manojlović, 2021; de Vasconcelos, 2018).

Early implementation of neuromuscular and proprioceptive training have proved its effectiveness in patients with LAS and CAI, resulting in significant improvement in ankle functional outcome measures, such as Foot and Ankle Disability Index (FADI), Foot and Ankle Ability Measure (FAAM), OLS, Star Excursion Balance Test (SEBT), and Y balance test (Grueva-Pancheva, 2021; McKeon et al., 2008; Wells et al., 2019), and reduces the prevalence of recurrent injury and functional instability (Postle et al., 2012; van der Wees et al., 2006; Zech et al., 2009).

Several studies indicate that balance training produces improvements in measures of both static and dynamic postural control in patients with CAI (Grueva-Pancheva, 2021; Jaber et al, 2018; Kidgell et al, 2007; McKeon, Hertel, 2008). In a systematic review of Webster & Gribble P (2010) authors concluded that functional rehabilitation intervention is associated with improved ankle stability for both postural control and self-reported function.

Alahmari et al (2021) found that 6 weeks of combined strengthening and proprioceptive training effectively improves stability, proprioception, balance, and self-reported functional outcomes in patients with CAI.

Based on the findings in the literature it becomes clear that neuromuscular and proprioceptive training is safe and effective and could be successfully implemented in patients with ankle sprains and CAI. However, some issues remain poorly discussed and further consideration is needed, such as when appropriate time to start proprioceptive training after acute ankle sprains is, what are the functional criteria to progress and how long the implementation of the proprioceptive training should continue.

In our patients proprioceptive training started as early as patients tolerated (within the 1st week after injury) by strictly observing the time frames and restrictions, related to the regeneration of the soft tissues and ligaments damaged during the initial trauma. Study of Wiebking et al. (2015**)** on anterior talofibular ligament (ATFL) strain have demonstrated that ATFL become taut when the ankle is placed into inversion, 12° plantar flexion, and 25° of internal rotation, so during the proliferative phase this position, inversion loading, especially in plantar flexion, and painful ankle movements were avoided. We believe that the early inclusion and correct selection of proprioception and balance training exercises, consistent with the process of regeneration of soft tissues damaged during trauma, are essential for the successful functional outcome. The early inclusion of proprioceptive training was effective and safe and no complications or exacerbation of symptoms have been found in our patients.

The effect of the application of proprioceptive training is indisputable, and most studies show research data on the effectiveness of 6-8 weeks of proprioceptive training, where a significant improvement in proprioception and balance is found, as demonstrated by static and dynamic balance tests (OLS, YBT, SEBT)

However is this period of training enough the deficit in proprioception and postural balance control to be overcome?

On the one hand, the application of proprioceptive training should continue until the results of the unaffected leg are reached. But in a systematic review, Wikstrom EA et al. (2010) found strong evidence that balance is bilaterally impaired after an acute LAS, and based on these findings authors suggest that the uninvolved limb should not be used as a reference for "normal balance" and patients with LAS should undergo balance training on both limbs.

On the other hand, the results of the balance assessment in healthy individuals could be used for comparison, but it is difficult to find appropriate match controls in terms of age, physical characteristics, functional requirements, according to lifestyle and practice of sports and recreational activities, etc.

We think that proprioceptive training should continue even after achieving a good functional level, sufficient to return to practicing sports and recreational activities from before the injury, as a prevention of recurrent ankle sprain, especially in individuals, which actively participated in sports and recreational activities.

6. CONCLUSION

The results of our study support the statement that early inclusion of a specialized individualized physiotherapy and training of the proprioception and the dynamic stabilization could successfully reduce the deficit in neuromuscular control and static and dynamic balance. The proprioceptive training should start as early as possible, should be individualized according to functional limitations and arthrokinematic changes of the whole kinetic chain of the injured lower limb and patients' capabilities, and designed to provide successful return to previous functional level of activity and participation in recreational and sports activities.

Further investigation examining the long-term effect of this proprioceptive training on larger contingent of patients with acute ankle sprain is warranted.

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