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Effectiveness of Proprioceptive Training on Pain and Functional Recovery in Individuals with Chronic Anterior Talofibular Ligament Injury

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Abstract

Background: The chronic injury of the anterior talofibular ligament represents a widespread source of lateral ankle instability, usually accompanied by persistent pain, functional limitations, and sprains. Proprioceptive deficits have a crucial role in the pathophysiology of the chronic ATFL dysfunction, hence representing a main target of treatment from a sensorimotor point of view.

Objective: This study aims at assessing the effectiveness of proprioceptive training on pain reduction and functional recovery in individuals diagnosed with a chronic ATFL injury.

Methodology: A randomized controlled experimental design was used involving 30 participants aged 18-60 years with a clinically diagnosed chronic injury to the ATFL. Subjects were then randomly assigned into an experimental group that received a structured 6-week proprioceptive training protocol and a control group that underwent conventional physiotherapy. The outcome measures used in the study were VAS for pain and FADI, which were measured pre- and post-intervention.

Results: Significant improvements in pain and functional scores were seen in both groups. Yet, the experimental group had better results, with VAS scores going from 6.73 ± 1.48 to 1.93 ± 0.77 ($p < 0.0000015$) and FADI scores going from 84.6 ± 9.94 to 25.86 ± 10.71 ($p < 0.0000000033$). The control group improved, but to a lesser extent.

Conclusion: Proprioceptive training is superior to conventional physiotherapy for pain relief and functional recovery in chronic ATFL injury. These findings justify the incorporation of proprioceptive modalities into the standard rehabilitation protocol for lateral ankle instability.

Keywords: Chronic ATFL Injury, Proprioceptive Training, Ankle Instability, Functional Recovery, Visual Analogue Scale (VAS), Foot and Ankle Disability Index (FADI)

INTRODUCTION

Chronic ATFL injury represents a persistent dysfunction of the most commonly injured component of the lateral ankle ligament complex, typically as a result of repeated ankle sprains or inadequately rehabilitated

acute injuries.

The ATFL is an important lateral ankle stabilizer that links the fibula to the talus and provides primary resistance against inversion and plantarflexion stresses. Chronic injury often occurs from repeated inversion trauma seen in athletes or individuals who participate in impact sports or activities that involve quick changes in direction. Over time, successive microtrauma or inadequate ligament healing leads to structural laxity, disorganization of collagen fibers, and impairment of proprioceptive feedback. The clinical presentation of patients with chronic ATFL injury involves persistent ankle instability, frequent giving-way episodes, localized pain over the anterolateral aspect of the ankle, and decreased functional performance. Symptoms are typically exacerbated during dynamic activities involving running, jumping, or sudden changes in direction. Positive anterior drawer and talar tilt tests may suggest mechanical instability, while impairment of balance and joint position sense implies functional instability. Ligamentous thickening, partial tears, and associated pathology such as synovitis or osteochondral lesions may also be demonstrated on MRI studies. If chronic ATFL injuries are left unaddressed, over time, they may predispose the patient to further ligamentous damage, peroneal tendon dysfunction, and early post-traumatic osteoarthritis. Due to this consideration, early recognition and comprehensive rehabilitation-performed through proprioceptive exercises, neuromuscular re-education, and functional strengthening-are necessary to restore stability to the joint and prevent recurrences while optimizing long-term outcomes. Proprioceptive training is specific rehabilitation aimed at improving the ability of the body to sense the position of joints, movements, and orientation in space, which is crucial for motor control, balance, and injury prevention.

Proprioception is best described as the internal awareness of the body regarding the position and movement of its limbs, mediated through the action of mechanoreceptors within the muscles, tendons, ligaments, and joint capsules. Injuries to the musculoskeletal system, including ligament sprains, fractures, and immobilization after surgery, are regularly associated with disrupted proprioceptive input. The hallmark of this disruption includes impaired neuromuscular control, balance deficits, and an increased incidence of re-injury. Proprioceptive training aims at the restoration of sensorimotor function through exercises that challenge joint stability, coordination, and reflexive responses. Such interventions generally include tasks of balance on unstable surfaces, dynamic joint repositioning drills, plyometric movements, and closed kinetic chain activities. Such training appears not only to improve postural control and functional performance but also to enhance cortical reorganization and motor learning in clinical conditions such as chronic ankle instability, ACL reconstruction, and stroke rehabilitation. In sports and orthopedic contexts, proprioception training is a vital part of return-to-play protocols, reducing recurrence rates and optimizing joint protection strategies. In both early and late-stage rehabilitation programs, significant benefits have been seen in regaining dynamic stability and preventing compensatory movement patterns.

METHODOLOGY

Study Design

This is a experimental study to be conducted in order to determine whether proprioceptive training is effective on functional outcomes following a diagnosis of chronic ATFL injury. It will follow a pre-test/post-test design with two parallel groups: one experimental group receiving proprioceptive training, and one control group receiving conventional physiotherapy.

Participants

Inclusion criteria:

- Inclusion Criteria: Adults aged 18–60 years with clinically and radiologically confirmed chronic ATFL injury ≥ 3 months post-injury.
- Positive anterior drawer test and/or talar tilt test
- History of recurrent ankle instability or sprains.

Exclusion Criteria:

- Acute ankle injuries (<3 months)
- Previous ankle surgery or fractures.
- Neurological or systemic disorders of balance or proprioception.
- Participation in organized proprioceptive training over the past 6 months.

Sample Size

At least 30 participants will be recruited and randomly distributed into two groups, with 15 participants in each. Sample size estimation will follow previous studies that have assessed proprioceptive interventions in lateral ankle instability, assuming a power of 80% at $\alpha = 0.05$.

Intervention Protocol

Proprioceptive Training Protocol – Experimental Group

Phase	Duration	Exercise Components	Purpose
Phase 1: Initiation	Week 1–2 (3 sessions/week)	- Static balance board holds - Single-leg stance on firm surface - Joint position imitation (visual feedback)	Activate mechanoreceptors, improve static postural control
Phase 2: Progression	Week 3–4 (3 sessions/week)	- Dynamic balance board movements - Single-leg stance on foam/wobble pads - Joint position imitation (no visual feedback)	Enhance proprioceptive acuity and neuromuscular coordination
Phase 3: Integration	Week 5–6 (3 sessions/week)	- Plyometric drills (hops, jump landings) - Perturbation training (manual/mechanical) - Sport-specific movement tasks	Restore dynamic stability, simulate real-life instability, improve motor response

Training Principles

- Session Duration: ~30–40 minutes
- Supervision: Conducted by a trained physiotherapist
- Progression Criteria: Based on participant tolerance, performance, and safety
- Safety Measures: Use of ankle braces if needed during high-demand tasks

Conventional Physiotherapy Protocol – Control Group

Phase	Duration	Exercise Components	Purpose
Phase 1: Mobility Restoration	Week 1–2 (3 sessions/week)	- Passive and active range of motion (ROM) exercises - Ankle circles, dorsiflexion/plantarflexion drills	Restore joint mobility, reduce stiffness, and promote synovial fluid circulation
Phase 2: Strengthening & Flexibility	Week 3–4 (3 sessions/week)	- Isometric and isotonic strengthening of ankle musculature (e.g., theraband resistance) - Static and dynamic stretching of calf, peroneal, and tibialis muscles	Improve muscular support around the ankle and enhance soft tissue flexibility
Phase 3: Functional Conditioning	Week 5–6 (3 sessions/week)	- Progressive resistance training - Manual therapy (e.g., soft tissue mobilization, joint glides) - Functional mobility drills (e.g., heel raises, step-ups)	Reinforce joint stability, reduce pain, and prepare for daily functional activities

Training Principles

- Session Duration: ~30–40 minutes
- Supervision: Conducted by a licensed physiotherapist
- Progression Criteria: Based on pain tolerance, range of motion gains, and strength improvements
- Safety Measures**:** Monitoring for signs of overuse or exacerbation of symptoms

Outcome Measures

Assessments will be performed at baseline and post-intervention (week 6):

- Visual Analogue Scale (VAS) for pain
- Foot and Ankle Disability Index (FADI)

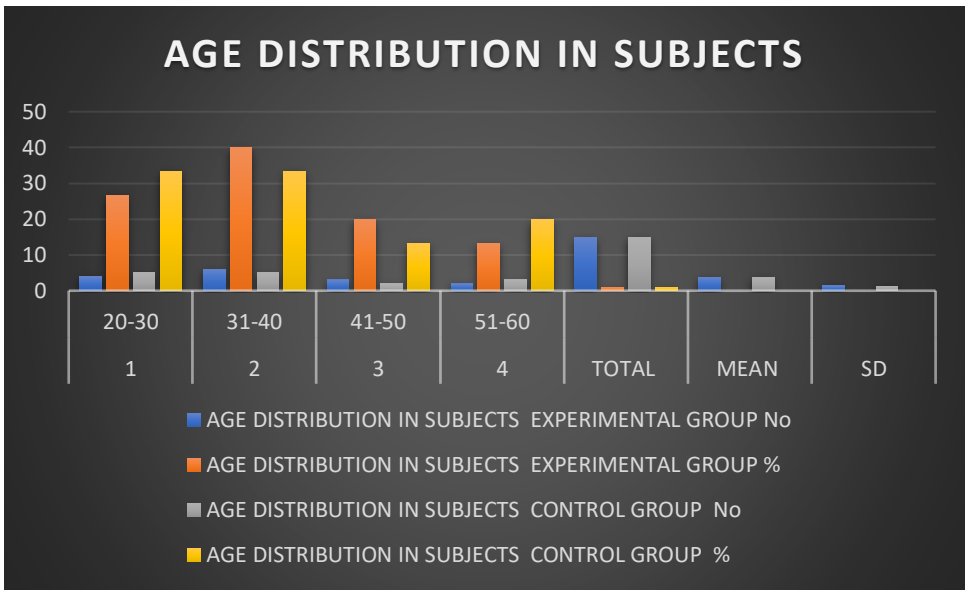
Data Analysis

Demographic data will be summarised using descriptive statistics. Between-group comparisons will be made by Mann–Whitney U tests, depending on the normality of data distribution. Within-group changes will be assessed by paired t-tests or Wilcoxon signed-rank tests. The level of significance will be set at a p-value < 0.05.

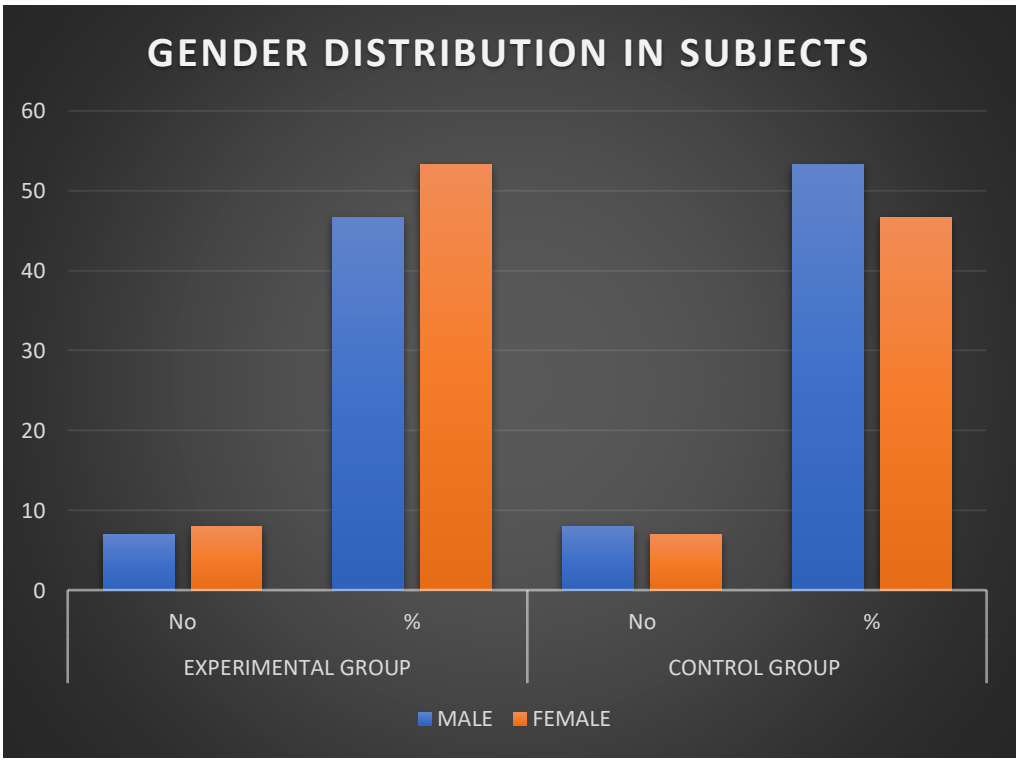
RESULTS

AGE DISTRIBUTION IN SUBJECTS					
		EXPERIMENTAL GROUP		CONTROL GROUP	
S.No	Age in years	No	%	No	%
1	20-30	4	26.6	5	33.3
2	31-40	6	40	5	33.3
3	41-50	3	20	2	13.3

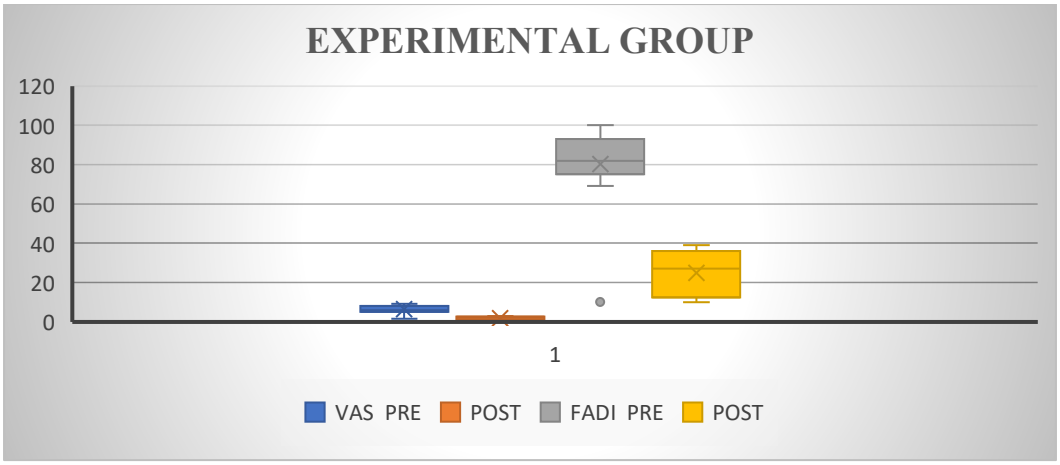
4	51-60	2	13.3	3	20
TOTAL		15	100%	15	100%
MEAN		3.75		3.75	
SD		1.479019946		1.299038106	



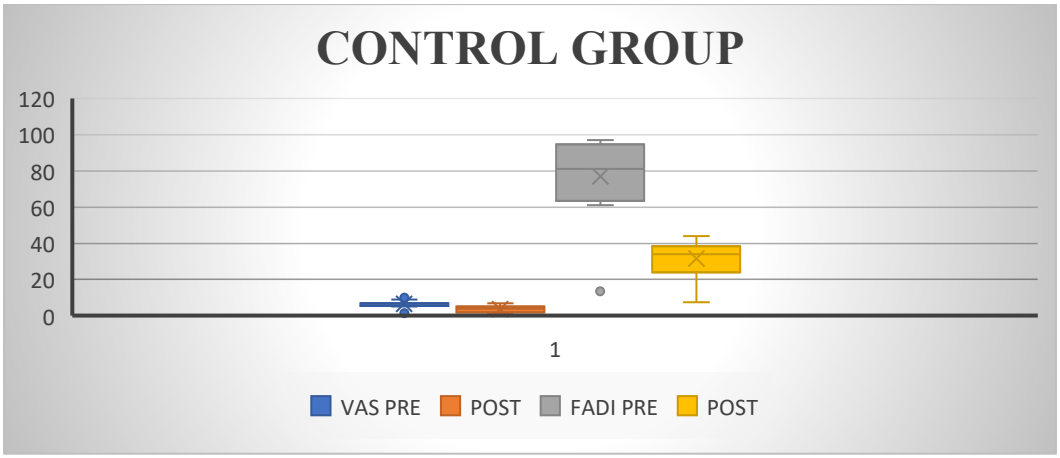
GENDER DISTRIBUTION IN SUBJECTS					
S.No	Gender	EXPERIMENTAL GROUP		CONTROL GROUP	
1	MALE	7	46.6	8	53.3
2	FEMALE	8	53.3	7	46.6



EXPERIMENTAL GROUP							
		PRE TEST		POST TEST		PAIRED T- TEST	
S. No	OUTCOME MEASURES	RANGE	MEAN ± SD	RANGE	MEAN ± SD	T-STAST	P VALUE
1	VAS	5-9	6.73 ± 1.48	1-3	1.93 ± 0.77	9.61	0.00000015 (Highly significant improvement)
2	FADI	72-100	84.6 ± 9.94	10-39	25.86 ± 10.71	13.01	0.0000000033 (Highly significant improvement)



CONTROL GROUP							
		PRE TEST		POST TEST		PAIRED T- TEST	
S. No	OUTCOME MEASURES	RANGE	MEAN ± SD	RANGE	MEAN ± SD	T-STAST	P VALUE
1	VAS	5-10	6.93 ± 1.4	2-7	3.86 ± 1.586	4.77	0.00030 (Significant improvement)
2	FADI	70-95	81.0 ± 13.58	20-43	32.86 ± 7.56	10.29	0.000000066 (Highly significant improvement)



Statistical evaluation of the data was performed with a paired t-test and showed a significant improvement for both groups in all outcome measures.

In the Experimental Group, VAS scores illustrated a significant reduction in pain, with values at pre-test from 5–9 (mean ± SD: 6.73 ± 1.48) and at post-test from 1–3 (mean ± SD: 1.93 ± 0.77). The calculated t-value of 9.61 and p-value of 0.00000015 reflected a highly significant improvement after the intervention. Similarly, the FADI scores indicated significant improvement in functional ability, with values at pre-test ranging between 72–100 (mean ± SD: 84.6 ± 9.94) and at post-test ranging between 10–39 (mean ± SD: 25.86 ± 10.71). Correspondingly, the t-value of 13.01 and p-value of 0.0000000033 further confirm highly significant improvement in the functional performance after the treatment.

There was also a statistically significant improvement in the Control Group, though it was comparatively less pronounced. VAS scores in the range of 5–10 (mean ± SD: 6.93 ± 1.4) during pre-test decreased to 2–7 (mean ± SD: 3.86 ± 1.586) during post-test. These subjects of the Control Group recorded a t-value of 4.77 and p-value of 0.00030, thus inferring a significant reduction in pain. Similarly, the FADI score improved from 70–95 (mean ± SD: 81.0 ± 13.58) to 20–43 (mean ± SD: 32.86 ± 7.56) with a t-value of 10.29 and p-value of 0.000000066, showing a highly significant improvement in functional outcomes.

Overall, both groups improved after the intervention; however, the experimental group showed greater statistical significance and clinical effectiveness. This indicated that the applied intervention protocol was indeed more effective in pain reduction and improvement of functional recovery compared with the control treatment.

DISCUSSION

The purpose of the present study was to assess the efficacy of proprioceptive training on pain and functional recovery in patients with chronic injury to the ATFL. The results indicated a statistically significant increase in all outcome measures of both groups. However, gains were much larger in the experimental group. Specifically, subjects receiving proprioceptive training showed a significant reduction in pain (VAS: mean ± SD from 6.73 ± 1.48 to 1.93 ± 0.77) and a significant enhancement in functional ability (FADI: mean ± SD from 84.6 ± 9.94 to 25.86 ± 10.71), both with highly significant p-values ($p < 0.000001$). These results confirm the hypothesis that proprioceptive training is of added benefit over traditional physiotherapy techniques.

The reason for the better results among the subjects in the experimental group was because proprioceptive exercises intrinsically include neuromuscular re-education and sensorimotor stimulation. Proprioceptive training enhances joint position sense, reflexive stability, and dynamic control through the facilitation of mechanoreceptors, promoting cortical reorganization. Such abilities are critical to deficits resulting from a chronic ATFL injury. This finding agrees with that of a meta-analysis conducted by Yin et al. (2025), which stated that proprioceptive neuromuscular facilitation significantly improves functional deficits in chronic ankle instability. Similarly, Paul and Sanjay (2019) found that proprioceptive training outperformed resistance training in improving perceived stability and reducing recurring sprains in patients with lateral ankle ligament injuries.

Besides, Gandhi et al. (2021) noted the anatomical intricacy of the ankle joint and the vital part proprioceptive input plays in maintaining postural control and preventing reinjury. Their experimental study on healthy subjects further validated the efficacy of proprioceptive interventions in enhancing balance and joint coordination. These findings collectively support the results of the current study and

further ensure that the clinical relevance of the incorporation of proprioceptive protocols in rehabilitation programs in cases of chronic ATFL dysfunction is justified.

While the control group also saw statistically significant improvements in pain and function, the magnitude of change was comparatively lower: VAS mean ± SD from 6.93 ± 1.4 to 3.86 ± 1.586 and FADI mean ± SD from 81.0 ± 13.58 to 32.86 ± 7.56. This seems to indicate that conventional physiotherapy, while beneficial, may lack the sensorimotor specificity required for the full restoration of dynamic ankle stability. The integration of proprioceptive drills, such as balance board training, perturbation exercises, and joint position replication, appears to address these deficits more effectively.

In the findings of this study and supported by the existing literature, the relevance of proprioceptive training in the rehabilitation process after chronic injuries of the ATFL is emphasized. Its incorporation into clinical practice can lead to better results regarding pain reduction, functional recovery, and long-term protection of the joint. Further research using larger sample sizes and long-term follow-up is needed to confirm these findings and look into the neurophysiological mechanisms of proprioceptive adaptation.

LIMITATIONS

- Small sample size: Only 30 subjects were used; thus, the generalization to wider populations that suffer from chronic injuries of the ATFL might be limited.
- Short Duration of Intervention: The intervention period of 6 weeks might not fully capture the long-term effects or sustainability of proprioceptive gains, especially in athletic or high-demand populations.
- Long-term follow-up was missing after the intervention, thus relapse rates, re-injury, or retention of functional gains could not be tracked over time.
- Single-center design: This could potentially lead to a biased estimation of the environmental or therapist-related effects.
- Limited Outcome Measures: While VAS and FADI are validated tools, measures such as dynamic balance tests (e.g., SEBT), joint position sense, or electromyographic analysis might have provided deeper insight into neuromuscular adaptations.
- Homogeneity of Participants: Restricting the age range to between 18 and 60 years may exclude older adults or adolescents who experience chronic ATFL dysfunction and may respond differently to proprioceptive training.

SUGGESTIONS FOR FUTURE RESEARCH

- Increase Sample Size and Diversity: Include a larger and more diverse participant pool across multiple centers to enhance external validity.
- Longer periods of training and follow-ups, for instance 3–6 months, would provide an overview regarding the aspect of retention and recurrence.
- Include Objective Neuromuscular Metrics: Incorporate tools such as force plates, motion capture, or EMG to quantify proprioceptive and motor control improvements.
- Compare Modalities: Compare the effectiveness of proprioceptive training to that achieved by neuromuscular electrical stimulation, virtual reality balance training, or sensor-based feedback systems.
- Subgroup Analysis: To examine differential responses based on age, activity level, or severity of ligament damage in order to tailor rehabilitation protocols more precisely.

- Functional return-to-sport criteria should be integrated, including sport-specific outcome measures and readiness assessments for the athletic population.

CONCLUSION

The results of this investigation show that proprioceptive training is significantly more effective than standard physiotherapy in reducing pain and improving functional recovery in patients with chronic injury to the anterior talofibular ligament. Those in the experimental group did better in terms of VAS and FADI scores, respectively, which were indicative of a higher level of neuromuscular adaptation and joint stabilization. These findings confirm the indispensable role played by proprioceptive input for the restoration of sensorimotor control and dynamic ankle function in individuals with chronic ligamentous insufficiency.

This structured intervention protocol, involving balance board exercises, replication of joint position, perturbation training, and sport-specific drills, proved clinically relevant and statistically robust for the rehabilitation process. This research is supported by previous literature, such as the studies by Yin et al. (2025), Paul & Sanjay (2019), and Gandhi et al. (2021).

In summary, proprioceptive training should be considered the cornerstone in the rehabilitation process of chronic ATFL injuries and offers quantifiable benefits in pain reduction, functional performance, and long-term joint protection. Larger sample size studies with extended follow-up periods and neuromechanical testing are suggested to further validate and refine these findings.

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