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Research Article

Plyometric Training on Balance and Foot Function among Collegiate Football Players with Lateral Ankle Sprains: A Quasi-Experimental Study

Yukta Devanand[1], Shenbaga Sundaram Subramanian[1*], Priyanka Bai[1], Diovin Derose Vianni[1], Eunice Keren Singarayar[2], Fadwa Alhalaiqa[3]

1. Saveetha College of Physiotherapy, Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai, Tamil Nadu, India.
2. College of Physiotherapy, Sri Ramakrishna Institute of Paramedical Sciences, Coimbatore, Tamil Nadu, India.
3. College of Nursing, Qatar University, Doha, Qatar.

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ABSTRACT

Introduction: Ankle sprains are common in competitive sports, especially football, accounting for approximately 15–17% of collegiate athletic injuries. Lateral ankle sprains (LAS) occur frequently due to rapid directional changes, jumping, and intense landings. Plyometric training, involving explosive and dynamic movements, is gaining attention for its role in rehabilitation and injury prevention. This study aimed to evaluate the effectiveness of plyometric training on balance and foot function among collegiate football players with LAS.

Materials and Methods: Collegiate football players with LAS completed a four-week plyometric training program consisting of three 30-minute sessions per week that included Pogo hops, lateral jumps, forward jumps, and single-leg split squats. The values of the star excursion balance test (SEBT) and foot function index (FFI) scores pre- and post-intervention were compared using a paired-samples t-test with significance set at $P<0.05$.

Results: The study showed significant improvements in SEBT scores in the right (anterior: 83.5±6.2% to 87.6±5.9%, $P<0.001$) and left limbs (anterior: 82.9±6.4% to 87±6.1%, $P<0.001$), with similar gains in the posteromedial and posterolateral directions. FFI total scores also improved significantly (23.4±6.8 to 15.9±5.7, $t=8.62$, $P<0.001$), indicating better balance and foot function.

Conclusion: Plyometric training is typically effective at enhancing balance and foot function in collegiate football players recovering from LAS.

*** Corresponding Author:**
Shenbaga Sundaram Subramanian, Professor.
Address: *Saveetha College of Physiotherapy, Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai, Tamil Nadu, India.*
E-mail: *subramanian.scpt@saveetha.com*

Introduction

The musculoskeletal system often sustains ankle sprains, which are among the most prevalent injuries in athletes. A ligament sprain happens when tissues are stretched too far or torn, especially affecting the lateral ligament complex, deltoid ligament, or distal tibiofibular syndesmosis of the ankle joint [1]. Lateral ankle sprains (LAS) occur more frequently than medial sprains because of the ankle's anatomical design; mainly, the lateral malleolus projects further distally than the medial malleolus, resulting in reduced bony limitation to inversion, and the deltoid ligament on the medial aspect is significantly stronger than the lateral ligaments, particularly the anterior talofibular ligament (ATFL) [2]. Inadequate muscle strength and mechanical instability were linked to an increased risk of ligament injury [3]. When the ankle is pushed past its usual limits, especially during inversion and plantarflexion, the ATFL and calcaneofibular ligament (CFL) are the most frequently damaged.

Football is acknowledged as one of the most popular sports worldwide, including in India, where two teams of 11 players strive to score goals while defending their own. Postural sway and reaction time deficits have been documented in athletes with ankle instability, underscoring the need for targeted rehabilitation [4]. To improve performance and decrease the risk of injury, plyometric training, an approach to jump training that emphasizes explosive actions, has been widely incorporated into athletic conditioning routines, and a recent systematic review confirmed the growing body of evidence supporting plyometric exercise in football [5].

The likelihood of LAS is estimated to increase by a factor of 1.5 for each five-year age increment among football players aged 15–40 years [6]. To improve performance and decrease the risk of injury, plyometric training, an approach to jump training that emphasizes explosive actions, has been widely incorporated into athletic conditioning routines. This training enhances neuromuscular coordination, sensorimotor capabilities, and postural stability, which are essential for preventing repeated ankle sprains [7, 8].

Common LAS mechanisms involve forced inversion of a plantarflexed foot, resulting in significant strain or tearing of the ATFL, and occasionally, the CFL [9]. After injury, limited dorsiflexion frequently remained, leading to changed gait patterns, slower walking speed, and shorter stride length [10]. A minimum of 10° of dorsiflexion is necessary for normal ambulation, whereas sprinting requires 20–30°. The assessment of impairments of neuromuscular control is commonly performed using a single-leg balance test, which provides an indication of the functional stability of the foot and ankle [11]. Poor balance performance has been associated with disturbed foot biomechanics and reduced athletic performance [12].

Therefore, this study aimed to examine the impact of plyometric training on the balance and foot function of collegiate football players who had sustained a lateral ankle injury. This study aimed to determine whether a systematic plyometric intervention would enhance dynamic balance and functional performance of the foot, which are the most important parameters for athletic recovery and injury prevention in this group.

Materials and Methods

College football players with grade 1 or grade 2 LAS were recruited using convenience sampling from university football teams and related physiotherapy centers. The inclusion criteria included age between 18 and 25 years, a history of lateral ankle sprain within the last 2-8 weeks, and clearance to undergo supervised rehabilitation exercises from a team physician or physiotherapist. They were excluded based on a history of either fracture or surgery on the affected limb, grade 3 sprain, neurological or vestibular loss, musculoskeletal or balance-affecting conditions, or participation in other structured rehabilitation programs at the time of the study. Randomization was not possible because the study employed a quasi-experimental pre-post design with a single group. To reduce detection bias, the outcome measures were collected by a blinded assessor unaware of the study's goal and the intervention. The 60 participants were chosen with the help of the OpenEpi software, applying the 95% confidence level, statistical power of 80%, and the expected difference in the balance performance of 8 units between the groups in the previous literature; the calculation of the expected attrition rate was also included (10-15%). Informed consent was obtained from all participants.

Procedure

Following recruitment and baseline assessment, the participants completed a four-week training program of plyometric exercises designed to enhance dynamic balance, proprioception, and foot function. Training sessions were performed under the supervision of a qualified physiotherapist, three times weekly and lasted approximately 30 minutes. The intervention protocol consisted of gradually progressed plyometric and strengthening exercises, focusing on controlled landing mechanics and ankle stability:

Week 1: Double-leg hops, line jumps (anterior-posterior and medial-lateral), seated calf raises. Week 2: Single-leg hops, side-to-side jumps, heel raises, inversion and eversion resistance bands. Week 3: Box jumps, single-leg balance hops, depth jumps with soft landings. Week 4: Advanced drills, e.g. bounding, lateral cone hops, and multidirectional hops simulating sport-specific movements.

Each session began with a ten-minute warm-up period (stretching and light jogging) and ended with a cool-down period. Exercise intensity and complexity were increased subjectively based on the participant's tolerance and symptom response. Participants were asked to report any discomfort, and modifications to the training were made when needed.

Outcome assessments were conducted at baseline (pre-test) and after four weeks (post-test) and were administered by the same blinded assessor to ensure consistency.

Outcome measures

The star excursion balance test (SEBT) provides an easy, reliable, and cost-effective alternative to sophisticated instrument-based assessments. As a measure of dynamic balance, the SEBT offers a more accurate assessment of lower-limb function than tests that assess instability only in static standing [13]. Dynamic balance was measured in the anterior, posteromedial, and posterolateral directions. The leg length of each participant, from the anterior superior iliac spine to the distal tip of the medial malleolus, was used to normalize the reach distances. For each direction, the mean of three trials was determined and reported as a percentage of leg length using the Equation 1:

1. Normalized reach distance (%)=Reach distance (cm)/Leg length (cm)×100

This normalization ensures comparability between participants and is generally accepted as controlling for anthropometric variability in SEBT performance.

The foot function index (FFI) is a patient-reported instrument that incorporates patient-centered values and assesses multiple dimensions of foot function. The 23 items of the FFI are classified into three subscales representing the impact of foot pathology on pain, disability, and activity restriction [14].

Statistical analysis

Statistical analysis was performed using IBM SPSS software, version 27, (IBM Corp., Armonk, NY, USA). Descriptive statistics (Mean±SD) were calculated for all variables. The Shapiro–Wilk test was used to assess the normality of data distribution. For within-group comparisons of pre- and post-intervention outcomes, paired-sample t-tests were applied to normally distributed data, while Wilcoxon signed-rank tests were used for non-normally distributed variables.

Given that six separate comparisons were made for SEBT (three directions per limb), a Bonferroni correction was applied to control for the risk of Type I error, yielding an adjusted level of significance of $P<0.0083$ (0.05/6). For all other outcomes, the significance threshold was set at $P<0.05$. Effect sizes (Cohen's d) were calculated for each outcome to assess the magnitude of change (small=0.2, medium=0.5, large=0.8). All t values were verified through independent analyses to ensure data accuracy and prevent duplication errors.

Results

Sixty collegiate football athletes diagnosed with LAS underwent a four-week plyometric training intervention. Within-group pre-test and post-test changes in dynamic balance (SEBT) and foot function (FFI) were tested.

Table 1 presents demographic and baseline characteristics of the participant cohort. The mean age was 20.83±1.24 years, and the mean body mass index was 22.35±1.92 kg/m^2, which falls within the normal weight range. Right-leg dominance was found in 86.7% of athletes, with most injuries occurring on the right side (56.7%). Participants had a mean of 6.24±2.11 years of football experience, and the mean time since the last ankle sprain was 8.5±2.3 weeks, thus allowing exclusion of acute injuries at baseline. The distribution of playing positions was similar to that of conventional collegiate teams, with the largest proportion of players in the midfield (36.7%).

Table 2 presents the results of the SEBT, normalized to limb length, demonstrating significant improvements across all directions and both limbs following the plyometric training intervention. As shown in Table 1, the anterior reach significantly increased from 83.5±6.2% to 87.6±5.9% for the right limb ($t=5.42$, $P<0.001$) and from 82.9±6.4% to 87±6.1% for the left limb ($t=5.15$, $P<0.001$). Similarly, the posteromedial reach exhibited marked gains, with the right limb improving from

Table 1. Demographic characteristics of participants (n=60)

Variables	Mean±SD/No. (%)
Age (y)	20.83±1.24
Height (cm)	173.65±6.82
Weight (kg)	67.42±7.15
Body mass index (kg/m²)	22.35±1.92
Dominant leg	Right: 52(86.7) Left: 8(13.3)
Duration of football experience (y)	6.24±2.11
History of lateral ankle sprain	Right: 34(56.7) Left: 26(43.3)
Time since last ankle sprain (weeks)	8.5±2.3
Playing position	Forward: 18(30) Midfielder: 22(36.7) Defender: 14(23.3) Goalkeeper: 6(10)

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Table 2. Comparison of pre-test and post-test SEBT scores (normalized to limb length [%])

Direction	Limb	Mean±SD		t Value	P
		Pre-test	Post-test		
Anterior	Right	83.5±6.2	87.6±5.9	5.42	<0.001
Anterior	Left	82.9±6.4	87±6.1	5.15	<0.001
Posteromedial	Right	85.1±5.8	89.2±5.3	5.89	<0.001
Posteromedial	Left	84.8±6	88.6±5.5	5.67	<0.001
Posterolateral	Right	83.9±6.5	87.5±5.9	5.01	<0.001
Posterolateral	Left	83.5±6.3	87±5.8	4.88	<0.001

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Table 3. Comparing pre-test and post-test values of FFI

Outcome	Mean±SD		t	P
	Pre-test	Post-test		
FFI (total)	23.4±6.8	15.9±5.7	8.62	<0.001

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85.1±5.8% to 89.2±5.3% (t=5.89, P<0.001) and the left limb from 84.8±6% to 88.6±5.5% (t=5.67, P<0.001). The posterolateral reach also showed significant enhancement, increasing from 83.9±6.5% to 87.5±5.9% on the right side (t=5.01, P<0.001) and from 83.5±6.3% to 87±5.8% on the left side (t=4.88, P<0.001). These results indicate a consistent and statistically significant improvement in dynamic balance performance across all tested directions, suggesting that plyometric training enhances postural control and functional stability in collegiate football players with LAS.

Table 3 presents the results of the FFI, which shows a statistically significant post-intervention improvement. The mean total FFI decreased from 23.4±6.8 at baseline to 15.9±5.7 at follow-up, indicating a significant improvement in pain, disability, and activity limitation, usually accompanied by LAS. The observed difference was significant (t=8.62, P<0.001), thereby demonstrat-

ing increased foot function and overall functional capacity among collegiate football players following completion of the plyometric training program.

Discussion

The primary objective of the present investigation was to investigate the impact of a plyometric training program on plantar foot surface function and balance in collegiate football athletes diagnosed with LAS. Following a four-week plyometric intervention, participants showed improved compensatory balance and foot function. Prior literature has documented a close link between functional ankle instability (FAI) and reduced dynamic balance, which can predispose to recurrent ankle injury [15]. Moreover, impairments in proprioception, muscular strength, flexibility, and neuromuscular control have been identified as contributory factors that increase re-injury risk in athletic populations [16].

Results showed a statistically significant increase in composite scores from pre-test to post-test, indicating improved dynamic balance quality. Such gains are understandably due to increased proprioceptive input and improved neuromuscular coordination [17]. These observations are consistent with previous reports, in which plyometric training was found to enhance joint proprioception, muscular power, vertical jump performance and acceleration, and overall movement efficiency [18]. Ankle range of motion is another vital factor in determining landing mechanics and the quality of functional movement. Existing evidence suggests that athletes with FAI have aberrant landing strategies associated with kinematic restrictions in dorsiflexion and plantarflexion [19].

Additionally, plyometric interventions modulate muscle activation patterns in healthy athletes [20]. The current investigation supports the idea that plyometric training enhances proprioceptive acuity in persons with ankle instability through repeated stimulation of the cutaneous and joint mechanoreceptors, thereby increasing the interactions between the central nervous system and its capacity to discriminate joint position and movement [21]. Increases in muscular power post plyometric training were attributed to adaptive changes in muscle fibers, tendinous tissues, and neural pathways that improved contraction velocity and force output without corresponding changes in muscle morphology [22]. These adaptations were made possible by the efficient utilization of elastic energy during the stretch-shortening cycle, which enables high power output at the expense of reduced recruitment of motor units [23, 24].

Collectively, the findings are in agreement with current evidence suggesting that plyometric training is at least as good as, if not better than, standard resistance training in enhancing muscular strength, dynamic balance, proprioception, and neuromuscular performance among athletes rehabilitating from LAS.

Study limitations

This investigation faced several limitations, such as a small sample size, a shorter training period, and the absence of a control or comparison group, which make generalizing the results difficult. Furthermore, dependence on subjective assessment techniques could have incurred response bias. Unmonitored extraneous variables, such as routine physical activity, dietary practices, sleep quality, previous injuries, use of ankle supports or taping, and participation in other exercise programs, may have had similar effects on the observed results. Consequently, these confounding elements might have modulated improvements in balance and foot function independent of the plyometric training intervention.

Recommendation for future research

Future studies should use randomized controlled designs encompassing broader and more heterogeneous populations and include objective measures. In addition, further follow-up periods and comparative analyses with other forms of rehabilitation are recommended.

Conclusion

This investigation found that plyometric training led to measurable improvements in balance and foot function among collegiate football players with LAS. The authors postulated that performing specific plyometric exercises targeting the lower extremity (forward-jump drills, lateral side jumps, pogo hops, and high-impact single-leg split squats) resulted in significant gains in foot function and balance. In conclusion, a four-week plyometric training program can significantly improve recovery and functional restoration in individuals struggling to overcome an LAS during rehabilitation, and this model is worthy of consideration as an evidence-based therapeutic strategy.

Ethical Considerations

Compliance with ethical guidelines

The research received an Institutional Scientific Review Board certificate from Saveetha College of Physio-

therapy, Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai, India (Code: 29/032/2024/ISRB/SR/SCPT).

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Authors' contributions

All authors contributed equally to the conception and design of the study, data collection and analysis, interpretation of the results, and drafting of the manuscript. Each author approved the final version of the manuscript for submission.

Conflict of interest

The authors declared no conflict of interest.

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