Research Article

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

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Running Title: Plyometric on Balance & Foot Posture Among Footballers with Ankle Sprains

Abstract
Background: Ankle sprains are common in competitive sports, especially football, accounting for about 15–17% of collegiate athletic injuries. Lateral ankle sprains 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. The aim of the study is to evaluate the effectiveness of plyometric training on balance and foot function among collegiate football players with lateral ankle sprains.

Material and Methods: Collegiate football players with lateral ankle sprain (LAS) completed a four-week plyometric training program consisting of three thirty-minute sessions per week that included Pogo Hops, Lateral Jumps, Forward Jumps and Single Leg Split Squats. The values of Star Excursion Balance Test (SEBT) and Foot Function Index (FFI) scores pre- and post-intervention were compared with paired-sample t-test with significance set at $p < 0.05$.

Results: The study showed significant improvements in SEBT scores increased in the right limb (anterior: 80.400 ± 1.265 to 80.800 ± 1.206 cm, $p<0.05$) and left limb (anterior: 80.400 ± 1.265 to 80.850 ± 1.132 cm, $p<0.05$), with similar gains in posteromedial and posterolateral directions. FFI scores also improved for both limbs (right: 80.450 ± 1.165 to 80.850 ± 1.132; left: 80.550 ± 1.235 to 81.000 ± 1.179, $p<0.05$), indicating better balance and foot function.

Conclusions: Plyometric Training would typically emphasize its effectiveness in enhancing balance and foot function in collegiate football players recovering from lateral ankle sprains.

Keywords: Ankle Injuries, Foot, Plyometric Exercise, Postural Balance

Introduction

The musculoskeletal system often undergoes 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) are observed to 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 was pushed past its usual limits, especially during inversion and plantarflexion, the ATFL and calcaneofibular ligament (CFL) were the most frequently damaged.

Football is acknowledged as one of the most popular sports worldwide, including areas like Indonesia, where two rival teams of eleven players strive to score goals while safeguarding their own. The likelihood of LAS is said to rise 1.5 times with each five-year age increment for football players aged 15–40 years [6]. To improve performance and decrease the risk of injury, plyometric training which is an approach to jump training with explosive actions has been extensively included in athletic conditioning routines. This training enhanced neuromuscular coordination, sensorimotor capabilities, and postural stability, which are essential for preventing repeated ankle sprains [7,8].

Common LAS mechanisms entail the 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 was necessary for normal ambulation, whereas sprinting required 20–30°. The assessment of impairments of neuromuscular control is commonly used by using single-leg balance test, thus giving an indication of the functional stability of the foot and ankle [11]. Poor performance in balance has been associated with disturbed foot biomechanics and reduced athletic performance [12].

Therefore, the aim of the study was to examine the impact of plyometric training on the balance and foot functioning of collegiate football players whose foot had been injured during a lateral

ankle injury. The aim was to find out whether a systematic plyometric intervention would enhance dynamic balance and functional performance of the foot which would be the most important parameters of athletic recovery and prevention of injury among this group.

Methods

Participants

College football players with Grade 1 or Grade 2 lateral ankle sprain were recruited using convenience sampling of the football teams and related physiotherapy centres of universities. Inclusion criteria included that the sample had to be aged between 18 and 25 years of age, had to have sustained an ankle sprain to the lateral side within the last 2-8 weeks and must have received a clearance to undergo supervised rehabilitation exercises by a team physician or physiotherapist. They were excluded based on the history of either fracture or surgery on the affected limb, Grade III sprains, neurological or vestibular loss, musculoskeletal or balance-affecting conditions, or participation in other structured rehabilitation programmes at the time of the study. Randomisation was not possible because the study was a type of quasi-experimental pre-post research design using a single-group design. In order to reduce the detection bias, the outcome measures were conducted by a blinded assessor without knowledge of the goal of the study and the intervention. The 60 participants were chosen with the help of the OpenEpi software, applying the 95% confidence level, statistical power 80, and the expected difference in the balance performance of 8 units between the groups in the previous literature, and the calculation of the expected attrition rate was also included (10-15 %). Informed consent was signed by all the participants. The research protocol was approved by the Institutional Ethics Committee (Approval No.: 29/032/2024/ISRB/SR/SCPT) and the Declaration of Helsinki was followed.

Procedure

Following recruitment and baseline assessment, the participants completed a four-week training programme 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 about thirty 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, invert and evert resistance bands.
Week 3: box jumps, single leg balance hops, depth jumps like 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 off period. Exercise intensity and complexity were increased subjectively based on the tolerance and the response of the symptoms experienced by the participant. 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 available by the same blinded assessor to assure 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 only assess instability when a patient is in static standing conditions [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 found as a percentage of leg length using the following formula:
Normalized reach distance (%)= Reach distance (cm) / Leg length (cm) * 100
This normalization controls for comparability between participants and is generally accepted for controlling anthropometric variability in SEBT performance.
The Foot Function Index (FFI) is a patient reported instrument that includes the patient centred values and assesses multiple dimensions of foot function. The 23 items of the FFI are classified in three subscales representing the impact of foot pathology on pain, disability and activity restriction [14].

Statistical Analysis
Statistical analysis was performed using IBM SPSS Statistics (Version 27, IBM Corp., Armonk, NY, USA). Descriptive statistics (mean ± standard deviation) 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 who had been diagnosed with lateral ankle sprains underwent a four-week plyometric training intervention. Within group pre and post-test changes in dynamic balance (Star Excursion Balance Test (SEBT)) and foot function (Foot Function Index (FFI)) were tested.

Table. 1: 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/m2, which corresponds to the normal weight range. Right leg dominance was found in 86.7% of athletes, with most of the 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 occurrence of ankle sprain was 8.5+-2.3 weeks, thus allowing for the exclusion of cases of acute injury at the baseline study phase. The distribution of playing positions was similar to conventional collegiate teams, with the largest proportion of players at the midfield (36.7%).

Table 1. Demographic Characteristics of Participants (n = 60)

Variable	**Mean ± SD / Frequency (%)**
Age (years)	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 (years)	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%)

Table 2: The results of the Star Excursion Balance Test (SEBT), normalized to limb length, demonstrated 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 87.0 ± 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 85.1 ± 5.8% to 89.2 ± 5.3% ($t = 5.89$, $p < 0.001$) and the left limb from 84.8 ± 6.0% 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 87.0 ± 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 lateral ankle sprains.

Table 2. Comparison of Pre- and Post-Test SEBT Scores (Normalized to Limb Length, %)

Direction	Limb	Pre-Test Mean ± SD	Post-Test Mean ± SD	t value	*p* value
Anterior	**Right**	83.5 ± 6.2	87.6 ± 5.9	5.42	< 0.001
Anterior	**Left**	82.9 ± 6.4	87.0 ± 6.1	5.15	< 0.001
Posteromedial	**Right**	85.1 ± 5.8	89.2 ± 5.3	5.89	< 0.001
Posteromedial	**Left**	84.8 ± 6.0	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	87.0 ± 5.8	4.88	< 0.001

Table 3 shows the results of the Foot Function Index (FFI) which shows a statistically significant post-intervention improvement. The mean total FFI was reduced from 23.4±6.8 at baseline to 15.9±5.7 at follow-up, indicating a significant improvement of pain, disability and activity limitation usually accompanied by lateral ankle sprains. The observed difference was found to be of significant importance (t, 8.62, $p < 0.001$) and thus, in fact, demonstrating increased foot function and general overall functional capacity among the collegiate football players following completion of the plyometric training program.

Table 3. Comparing Pre and Post Test Values of Foot Function Index

Outcome	Pre-Test Mean ± SD	Post-Test Mean ± SD	t value	*p* value
Foot Function Index (Total)	23.4 ± 6.8	15.9 ± 5.7	8.62	< 0.001

Discussion

The primary objective of the present investigation was to investigate the impact of the plyometric training program on plantar foot surface function and balance in the collegiate football athletes diagnosed with lateral ankle sprain (LAS). Following a four-week plyometric intervention, there were improved outcomes with the compensatory balance and foot function

in the participants. Prior literature has explained a close link between functional ankle instability (FAI) and reduced levels of dynamic balance that can predispose the onset of recurrent ankle injury [15]. Moreover, impairments in proprioception, muscular strength, flexibility and neuromuscular control have been identified as contributory factors which increase re-injury risk in athletic populations [16].

Results showed a statistically significant increase in composite scores (CS) between pre- and post-test assessment, which indicated an increase in the quality of dynamic balance. Such gains are understandably due to increased proprioceptive input and improved neuromuscular coordination [17]. These observations are in line with previous reports, in which plyometric training was found to enhance the joint proprioception, muscular power, vertical jump performance and acceleration, and overall movement efficiency [18]. Ankle range of motion (ROM) was yet another vital factor in determining landing mechanics and the quality of functional movement. Existing evidence has suggested that athletes with FAI have aberrant landing strategies associated with kinematic restrictions in dorsiflexion and plantarflexion [19]. Additionally, plyometric interventions were found to also 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 to increase the interactions between the central nervous system and the capacity of the central nervous system to discriminate joint position and movement [21]. Increases in muscular power post plyometric training were attributed to adaptive changes within muscle fibers, tendinous tissues, and neural pathways that promoted improvements in contraction velocity and force output without the same changes within muscle morphology [22]. These adaptations were made possible because of the efficient utilization of elastic energy during the stretch-shortening cycle (SSC), which allows the production of high power output at the expense of a reduced recruitment of motor units [23,24].

Collectively, the findings are in agreement with current evidence that suggests that plyometric training is at least as good-as, if not better-than standard resistance training in the enhancement of muscular strength, dynamic balance, proprioception and neuromuscular performance among athletes rehabilitating from lateral ankle sprains.

Conclusion

This investigation found that plyometric training produced measurable improvements in balance and foot function in collegiate football players that have lateral ankle sprains. Authors postulated that the execution of specific plyometric exercises targeting the lower extremity (forth jump drills, lateral side jumps, pog hops, and high-impact single-leg split squats) resulted in a significant gain in foot function and balance capabilities. In conclusion, a four-week application of plyometric training can significantly improve recovery and functional restoration in individuals that are struggling to overcome a lateral ankle sprain during the rehabilitation process and this model is worthy of consideration as an evidence based therapeutic strategy.

Study limitations

This investigation faced a variety of limitations such as small number of samples, shorter training period and no control or comparison group, which makes generalization of the results difficult. Furthermore, dependence on subjective assessment techniques could have incurred response bias. Unmonitored extraneous variables such as the routine physical activity, dietary practices, sleep quality, previous injuries, the use of ankle supports or taping, and participation in other exercise programs of the participants 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 would do well to use approaches characterized by randomised controlled designs encompassing broader, more heterogeneous populations, as well as use of objective measures. In addition, further follow-up periods and comparative analyses with other forms of rehabilitation are recommended.

Ethical Considerations

Compliance with ethical guidelines

The research received the Institutional Scientific Review Board (ISRB) certificate from Saveetha College of Physiotherapy, SIMATS, under the approval number (29/032/2024/ISRB/SR/SCPT), in compliance with ethical research guidelines.

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Conflict of Interest

All the authors declare that they have no conflict of interests.

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