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Impact of lateral ankle sprains on physical function, range of motion, isometric strength and balance in professional soccer players

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ABSTRACT

Objective Lateral ankle sprains (LASs) are prevalent in soccer and can affect long-term performance, injury recurrence and risk for chronic ankle instability. This case–control study examined functional impairments associated with LAS in professional soccer players aged 17–21.

Methods 40 players were divided into 2 groups: 21 with a history of LAS and 19 healthy matched controls. Functional assessments included the Foot and Ankle Ability Measure (FAAM), Y Balance Test (YBT), Weight Bearing Lunge Test, Heel Rise Test, Side Hop Test, and ankle and hip isometric strength measurements.

Results Soccer players with a history of LAS exhibited significant deficits in dynamic balance, particularly in the anterior and composite YBT scores, with moderate effect sizes ($p<0.05$). FAAM scores also revealed functional limitations in daily activities and sports performance for the LAS group. No significant differences were observed in strength or mobility measures, including the Heel Rise, Side Hop and isometric tests. There were also no differences between injured and non-injured legs in the LAS group in the performance tests.

Conclusions These findings highlight the persistent deficits in dynamic balance following LAS, emphasising the need for targeted rehabilitation to mitigate the risk of reinjury and enhance performance in soccer players.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Lateral ankle sprains (LASs) are common in soccer and lead to long-term issues like injury recurrence and chronic ankle instability. LAS is linked to impaired dynamic balance and functional limitations, especially in athletes.

WHAT THIS STUDY ADDS

⇒ This study reveals that professional soccer players with a history of LAS experience persistent deficits in dynamic balance, despite no differences in strength or mobility between injured and non-injured legs.

⇒ Functional limitations remain significant in daily and sports activities, emphasising the need for targeted rehabilitation focused on balance.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The study highlights the importance of incorporating dynamic balance training in LAS rehabilitation to prevent reinjury.

⇒ It calls for further research into long-term balance impairments and suggests that sports teams should update rehabilitation practices to better address balance deficits in athletes recovering from LAS.

INTRODUCTION

Lateral ankle sprains (LASs) are among the most common injuries in soccer and pose a substantial risk to the long-term performance and career longevity of professional players.[1] In the fast-paced environment of professional soccer with rapid directional changes, sudden decelerations and frequent jumping, LASs account for up to 25% of all sports injuries.[1–3] Recurrence rates of LASs are higher than ACL injuries in professional soccer players.[1] LAS injuries can lead to chronic ankle instability (CAI). CAI is diagnosed when symptoms persist for 6 months or longer after an initial ankle sprain, with recurrent episodes of ankle ‘giveaway’ typically developing due to mechanical instability, functional instability (or both). Up to 40% of athletes with CAI experience recurrent acute sprains and prolonged functional impairment.[4] LAS has been identified as a potential cause of functional limitations that are crucial for optimal sports performance. Athletes with a history of LAS often exhibit reduced ankle dorsiflexion range of motion (DF ROM), which can impair essential movements such as running, cutting and jumping.[5 6] Additionally, deficits in isometric strength of the foot and ankle muscles, as well as the hip abductors—vital for stabilising the pelvis and postural stability—are commonly observed.[7–9] Balance, a critical factor in soccer performance, can be impaired and should be assessed in athletes with a history of LAS.[2] These postural stability impairments are closely linked to CAI and lead to deficits in proprioception and postural

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control, increasing the risk of reinjury during dynamic gameplay.[10 11] Recent studies emphasise the importance of targeted balance and proprioceptive training in addressing these deficits, with evidence suggesting that such interventions can significantly improve ankle stability and reduce the incidence of ankle sprains among soccer players.[3 7]

Unilateral restrictions can lead to imbalanced loading patterns, potentially resulting in interlimb asymmetries that influence lower extremity biomechanics.[5 12 13] While some evidence suggests that an asymmetry threshold of 10%–15% might increase the risk of injury, this is largely based on studies in athletes returning to sport after ACL reconstruction, and its relevance to LAS remains unclear.[5] In soccer players, for example, asymmetries exceeding 10% have been observed, though these may be influenced by the sport's functional demands. Moreover, a recent study highlighted significant reductions in ankle ROM that can begin in early childhood and worsen with age in soccer players.[14] To comprehensively evaluate functional impairments, researchers use the Foot and Ankle Ability Measure (FAAM), a validated tool for assessing functional limitations in individuals with LAS and CAI.[15] The FAAM has demonstrated strong associations with key measures of muscle strength, postural control and functional performance, making it a crucial instrument for capturing the broader impact of LAS on an athlete's ability to perform.[16]

Due to the high prevalence and potential long-term effects of LAS in soccer players, it is essential to understand the specific functional impairments associated with these injuries. The existing literature has shown ROM restrictions, weakness and balance deficits following ankle sprains.[2] There is currently no comprehensive evaluation that examines the above factors in professional soccer players after LAS. The study aims to provide a comprehensive assessment of ankle DF ROM, isometric strength of the foot flexors, extensors and hip abductors, dynamic balance as well as physical limitations (FAAM, Side Hop, Heel Rise Test (HRT)) in soccer players with a history of LAS.

Hypotheses were assumed in which (1) soccer players with a history of LAS would demonstrate worse performance than the healthy matched group and (2) lower limb with a history of injury would present higher deficits relative to the healthy limb. By evaluating these interrelated factors, this study seeks to inform more effective targeted rehabilitation strategies and possibly to help reduce the risk of recurrent injuries and associated performance limitations in high-risk populations.

MATERIALS AND METHODS

Participants

The study included 40 professional soccer players aged 17–21 years recruited from a soccer club. Players were recruited through interviews and discussions with the team coaches. A personal questionnaire was then used to verify the LAS information. Participants were divided into two groups: the LAS group (n=21), comprising players who had experienced an inversion ankle sprain within the past year, and the control group (n=19), consisting of players with no history of injury. Controls were matched to LAS participants based on gender, age, height, weight and physical activity level to minimise confounding variables and ensure comparable demographic characteristics. LASs were classified into three grades based on the severity of ligament damage and associated clinical features (table 1).[17] Inclusion criteria required participants to be actively engaged in soccer training, with the LAS group specifically including those with an inversion ankle sprain within the last year (low-grade injuries, ie, grades I and II) and completed injury rehabilitation. Exclusion criteria included lack of consent, unfamiliarity with study details or current health conditions preventing participation, high-grade LAS injury (III grade). Informed consent was obtained after explaining the study objectives and procedures. Screening and group assignment were conducted using a custom 19-item questionnaire. The questions were to assess injury history, training frequency, pain during training, dominant lower limb and additional physical activities, with LAS-specific questions on ligament damage grade, sprain frequency, affected limb, rehabilitation, return to sport (RTS) (whether they have returned to full participation in soccer, ie, training and matches) and time-loss (assessed as months/days, ie, time from injury to RTS).

Procedures

All tests were conducted in a prepared gym space at the club's training centre on the campus of the National Rugby Stadium in Poland between February and March 2024. Testing is administered by a sports physiotherapist

Table 1 Classification and clinical features of LAS

Grade		Ligament damage	Clinical features	Instability	Functional impact
Low grade	I	Mild stretching/ microscopic tearing	Minimal swelling, mild tenderness, no significant bruising	None	Minimal or no functional loss
	II	Partial tearing	Moderate swelling, tenderness and mild to moderate bruising	Mild to moderate	Noticeable limp, reduced motion
High grade	III	Complete rupture	Significant swelling, severe tenderness, marked bruising	Severe	Significant functional loss, prolonged rehabilitation or surgery may be required

LAS, lateral ankle sprain.

with 2 years of experience, under the supervision of a senior physiotherapist with 6 years of experience in clinical and experimental methods. To prevent fatigue from influencing the results, all tests were performed before the players' regular tactical training sessions. All raw data were recorded electronically and verified manually to minimise data entry errors. Consistency of measurement was maintained through the use of standardised forms. After data collection, researchers review the records to verify data quality.

Functional assessment

Participants completed the FAAM to evaluate functional limitations due to ankle or foot conditions, using a 5-point Likert scale. They rated their overall function on a 0%–100% scale prior to ankle pain and categorised their current function as normal, nearly normal, abnormal or severely abnormal.[15] It is reported that the FAAM is a reliable (0.89 for ADL, 0.87 for sports subscales), responsive and valid measure of physical function after ankle injury.[18]

The Y Balance Test (YBT) assessed dynamic balance, strength and proprioception. The test was conducted on a YBT kit with reach indicators positioned in anterior, posteromedial and posterolateral directions at 0°, 135° and 225° relative to the stance foot. Participants performed three trials per direction for each leg, reaching with the opposite leg while maintaining balance. Anterior, posterolateral and posteromedial reach distances were measured. Composite score was normalised to leg length and averaged to compute [(sum of the three reach distances/3)/leg length×100] to assess balance performance.[19] A recent systematic review showed that median inter-rater intraclass correlation coefficient (ICC) values were robust, with values of 0.88 (range: 0.83–0.96) for the anterior, 0.87 (0.80–1.00) for the posteromedial and 0.88 (0.73–1.00) for the posterolateral directions. Similarly, intra-rater reliability was consistent, with median ICC values of 0.88 (0.84–0.93), 0.88 (0.85–0.94) and 0.90 (0.68–0.94) for the anterior, posteromedial and posterolateral directions, respectively.[20]

The HRT was performed to evaluate calf muscle strength and endurance. Participants stood on a flat, non-slip surface with light support if needed, performing consecutive single-leg heel rises by lifting the heel off the ground to the maximum height and lowering it back in a controlled manner at a pace of 1 s up and 1 s down. The test continued until the participant could no longer maintain form, reach full height or report pain. The number of correctly performed heel rises was recorded, and the results were compared between injured and uninjured sides to identify muscle weakness or impaired function. The test demonstrated excellent reliability, with an ICC of 0.96.[21]

The Side Hop Test (SHT) assessed lower limb strength, agility and neuromuscular control. Participants stood on the test leg between two parallel lines marked 40 cm apart and hopped laterally over the lines as quickly as possible, ensuring control and balance. Performance was measured by the number of successful hops or the time taken, with errors repeated when necessary. Results were compared between injured and uninjured sides to identify functional deficits.[22] The ICC of the SHT was good to excellent (for the right leg=0.84 and for the left leg=0.96) in the study by Kockum and Heijne.[23]

The Weight Bearing Lunge Test (WBLT) was used to assess ankle DF ROM. Participants stood facing a wall with the test foot placed a set distance from the wall, allowing the knee to move forward until it lightly touched the wall without the heel lifting. The distance between the toes and the wall was adjusted to the participant's maximum range of dorsiflexion. Measurements were recorded as the distance from the big toe to the wall. The WBLT has been shown to be a reliable measure of ankle dorsiflexion, with reported ICC values of 0.98.[24]

The isometric maximal strength of the hip abductors, ankle plantar and dorsiflexion muscles was measured using the Lafayette Hand-Held Dynamometer (HHD) (Lafayette Instrument, USA). The methodology for conducting the measurements was consistent with the study by Mentiplay *et al*.[25] Participants were positioned comfortably lying supine, with the ankle in a neutral position. The dynamometer was placed against the forefoot for plantar flexion and against the dorsum for dorsiflexion. The hip abductors were assessed with the participant in a supine position with the hip and knee extended. Participants were instructed to push maximally for 5 s without compensatory movements while the examiner provided resistance. To assess ankle plantarflexion, the examiner's elbow (bent 90°) was supported against a wall to withstand the forces generated by the ankle muscles. Each measurement was performed three times, with a brief rest period (90 s) between trials to minimise fatigue, and the highest recorded value was used to determine maximal strength.[25] A procedure in line with the Mentiplay *et al* study showed that assessment of lower limb muscle strength using the HHD (also Lafayette Manual Muscle Testing System) has good to excellent reliability (coefficients >0.70) and moderate to excellent validity (ICCs=from 0.31 to 0.79).[25]

Statistical analyses

All analyses were conducted using Jamovi open-source software (V.2.5).[26] Graph design was performed using GraphPad Prism (V.10.3.0 for Windows, GraphPad Software, Boston, Massachusetts USA, www.graphpad.com). Data were analysed using a combination of parametric and non-parametric statistical methods, depending on the distributional characteristics of the variables. Prior to analysis, the normality of continuous variables was assessed using the Shapiro-Wilk test. Continuous variables were summarised as mean±SD for normally distributed data and as median±IQR for non-normally distributed data. For normally distributed variables, independent samples t-tests were used to compare means between the LAS and control groups. Mean differences (MDs) were

Table 2 Characteristics of the entire sample

Variable	Entire sample (mean±SD)	LAS group (mean±SD)	Control group (mean±SD)	P value
Age	17.52±0.96	17.71±0.90	17.32±1.00	0.9018
Weight	72.56±5.98	72.45±6.26	72.68±5.82	0.4520
Height	1.80±0.07	1.81±0.07	1.79±0.07	0.8049
Experience (years)	10.40±1.81	10.90±1.51	9.84±1.98	0.9665
BMI	22.50±1.36	22.23±1.41	22.79±1.27	0.0959
Trainings unit (per week)	5.05±0.32	5.10±0.44	5.00±0.00	0.8354
Additional motor trainings unit (per week)	1.20±0.65	1.33±0.80	1.05±0.40	0.9179

BMI, body mass index; LAS, lateral ankle sprain; S&C, strength and conditioning.

calculated alongside 95% CIs to assess the magnitude and precision of differences between groups. Cohen's d was calculated for parametric comparisons to quantify the effect size. For non-normally distributed variables, the Mann-Whitney U test was employed to compare medians between groups. Effect sizes for non-parametric comparisons were calculated using the rank-biserial correlation (r). A p<0.05 value indicated that the results were statistically significant.

Sample size was calculated based on the primary outcome (FAAM) and the secondary outcome (YBT). For the FAAM, a moderate effect size of 0.5 was used, which is commonly used to detect clinically relevant functional improvements in lower limb interventions,[18] resulting in a required sample size of 64 participants per group to achieve 80% power at a 5% significance level. For the YBT, with an expected effect size of 0.5 and an SEM of 7 cm (composite direction) based on previous studies, we calculated that 33 participants per group would be required to detect meaningful differences in dynamic balance.[27]

RESULTS

There were no significant differences between the LAS and control groups in terms of age, height, BMI, soccer experience, frequency and duration of training sessions, or the number of weekly strength and conditioning sessions (table 2).

Notably, 95% (n=19) of the injuries in the LAS group related to the dominant leg, with only 5% (n=1) affecting the non-dominant (ND) leg. The duration of time-loss due to LAS varied (27.8±12.7 days), with a minimum of 10.5 days (one athlete) and a maximum of 84 days (two athletes). All participants reported having undergone rehabilitation and returned to sport following their ankle sprain. Additionally, when asked about performing specific exercises as a preventive measure before training to avoid reinjury, none of the respondents confirmed engaging in such practices.

LAS versus control

Dynamic balance assessment

The results of the functional tests and strength assessments are presented in table 3 with effect sizes and MD in table 4. The Y Balance (Anterior) test revealed significant differences between the LAS and control groups for both the dominant (MD=5.12, 95% CI=−0.57 to 10.81, p=0.038, d=−0.58) and ND legs (MD=3.41, 95% CI=−0.70 to 7.51, p=0.051, d=−0.53) (figure 1). Additionally, the Y Balance Composite scores were significantly lower in the LAS group for both the dominant (MD=4.12, 95% CI=0.53 to 7.71, p=0.012, d=−0.73) and ND legs (MD=4.30, 95% CI=0.59 to 8.01, p=0.012, d=−0.74) (figure 2).

Functional activity scores

The FAAM scores indicated significant differences between the groups (tables 3 and 4, figure 3). The FAAM Activities of Daily Living Score was lower in the LAS group compared with the control group (p=0.003, r=0.46). Similarly, the FAAM Sports Score was reduced in the LAS group (p=0.007, r=0.46).

Functional tests and strength assessments

Functional tests did not reveal statistically significant differences between the groups. The WBLT showed no significant difference in DF ROM between the LAS and control group for both the dominant (MD=0.68, 95% CI=−0.74 to 2.10, d=0.24, p=0.226) and ND legs (MD=0.58, 95% CI=−1.06 to 2.23, d=0.18, p=0.286). Similarly, the Side Hop (D, MD=1.01, 95% CI=−2.20 to 4.22, d=0.16), (ND, MD=0.47, 95% CI=−3.04 to 3.98, d=0.07) and HRT test (D, MD=−3.61, 95% CI=−9.07 to 1.85, d=−0.33), (ND, MD=−6.53, 95% CI=−12.3 to −0.71, d = −0.57) results were not significantly different between the groups, for the dominant and the ND leg (p<0.05). Isometric force scores plantarflexion (D, MD=0.48, 95% CI=−2.18 to 3.14, d=0.09), (ND, MD=0.72, 95% CI=−1.31 to 2.75, d=0.18), dorsiflexion (D, MD=2.05, 95% CI=−0.62 to 4.72, d=0.38), (ND, MD=1.98, 95% CI=−1.21 to 2.75, d=0.31), hip abduction (D, MD=0.06, 95%CI=−1.49 to 1.61, d=0.02), (ND, MD=−1.47, 95% CI=−3.17 to 0.23, d=−0.44) showed

Table 3 Characteristics of variables

Variable	Entire sample (mean±SD)	Lateral ankle sprains (mean±SD)	Control group (mean±SD)	P value
D WBLT (cm)	8.75±2.78	8.43±2.68	9.11±2.93	0.2259
ND WBLT (cm)	8.88±3.21	8.60±3.01	9.18±3.48	0.2860
D Side Hop Test (points)	13.78±6.35	13.30±7.47	14.31±4.98	0.3063
ND Side Hop Test (points)	14.20±6.94	13.98±8.36	14.45±5.14	0.4141
D HRT (rep)	43.48±10.87	45.19±12.01	41.58±9.42	0.8527
ND HRT (rep)	43.38±12.00	46.48±14.43	39.95±7.52	0.9606
Dynamic Balance				
D YBT Anterior (cm)	61.10±9.10	58.67±8.40	63.79±9.29	0.0383*
ND YBT Anterior (cm)	58.48±6.56	56.86±6.52	60.26±6.30	0.0506
D YBT Posterolateral (cm)	102.10±8.01	100.67±9.08	103.68±6.50	0.1158
ND YBT Posterolateral (cm)	102.97±8.27	101.90±8.03	104.16±8.58	0.1991
D YBT Posteromedial (cm)	101.05±10.26	100.48±8.94	101.68±11.77	0.3596
ND YBT Posteromedial (cm)	100.62±11.40	99.00±10.24	102.42±12.59	0.1776
D YBT Composite (LL %)	92.45±5.93	90.49±6.11	94.61±5.04	0.0125*
ND YBT Composite (LL %)	91.55±6.14	89.50±6.11	93.81±5.48	0.0120*
Isometric strength (HHD)				
D plantar flexion force (kg)	22.11±5.17	21.88±4.29	22.36±6.10	0.8496†
ND plantar flexion force (kg)	22.06±3.95	21.72±3.64	22.44±4.34	0.5422†
D dorsiflexion force (kg)	29.46±5.26	28.49±4.01	30.54±6.30	0.1176
ND dorsiflexion force (kg)	28.67±6.22	27.73±4.62	29.71±7.61	0.1258†
D hip abduction force (kg)	17.66±2.99	17.63±2.58	17.69±3.47	0.4720
ND hip abduction force (kg)	17.73±3.43	18.43±3.89	16.96±2.74	0.9133
FAAM				
FAAM activities of daily living score (%)	99.4±1.35	98.9±1.70	100.0±0.00	0.0034†
FAAM sports score (%)	97.1±6.97	94.6±8.94	100.0±0.00	0.0069†

Differences between groups.
*p<0.05
†Mann-Whitney test
‡p<0.01
D, dominant; FAAM, Foot and Ankle Ability Measure; HHD, Hand-Held Dynamometer; HRT, Heel Raise Test; LL%, standardised with lower limb %; ND, non-dominant; WBLT, Weight Bearing Lunge Test; YBT, Y Balance Test.

no statistically significant differences between the groups for dominant and ND legs ($p<0.05$).

Injured versus non-injured leg analysis in the LAS group

The analysis of differences between the injured and non-injured legs within the group with a history of LAS injury is summarised in table 5. There were no statistically significant differences across the variables ($p<0.05$). The SHT and Y Balance Anterior showed a relatively moderate effect size ($r=0.450$ and $d=0.394$, respectively) when comparing injured and non-injured legs, though the differences did not reach statistical significance ($p=0.098$ and $p=0.086$, respectively).

DISCUSSION

The findings of this study provide valuable insights into the functional impairments associated with a history of LAS in professional soccer players. These deficits were particularly evident in dynamic balance measures, as assessed by the YBT (anterior and composite scores), as well as in ankle-related physical limitation scores measured by FAAM.

Implications of reduced dynamic balance

The significant reductions in Y Balance Anterior and Composite scores in the injured group underscore the possible impact of ankle injury on dynamic balance. The decrease in balance may have been caused by damage to proprioceptive sensors following ankle injury, as an impaired sense of joint position limits an athlete's ability to maintain stability during complex movements.[28] Our finding aligns with previous research that highlights the association between LAS and impaired proprioception, which can lead to diminished postural control and

Table 4 Effect sizes and MD for significant variables

Dynamic balance	LAS group (mean±SD)	Control group (mean±SD)	MD (95% CI)	P value	Effect size Cohen's d
D YBT anterior (cm)	58.67±8.40	63.79±9.29	5.1228 (−0.57 to 10.81)	0.0383*	−0.58
ND YBT anterior (cm)	56.86±6.52	60.26±6.30	3.4060 (−0.70 to 7.51)	0.0506	−0.53
D YBT composite (cm)	90.49±6.11	94.61±5.04	4.1196 (0.53 to 7.71)	0.0125*	−0.73
ND YBT composite (LL%)	89.50±6.11	93.81±5.48	4.3039 (0.59 to 8.01)	0.0120*	−0.74
FAAM	**LAS group (median, IQR)**	**Control group (median, IQR)**		**P value (Mann-Whitney U)**	**Effect size (r)**
FAAM activities of daily living score (%)	100.00 (2.38)	100.00 (0.00)		0.0034†	0.46 (medium effect)
FAAM sports score (%)	100.00 (7.14)	100.00 (0.00)		0.0069†	0.46 (medium effect)

*p<0.05

†p<0.01.

D, dominant; d, Cohen's d; FAAM, Foot and Ankle Ability Measure; HHD, Hand-Held Dynamometer; HRT, Heel Raise Test; LAS, lateral ankle sprain; LL%, standardised with lower limb %; MD, Mean Difference; ND, non-dominant; r, rank-order correlation coefficient; WBLT, Weight Bearing Lunge Test; YBT, Y Balance Test.

increased risk of reinjury during high-intensity activities such as soccer.[2 10 11] Gribble *et al* also found that American football players who sustained LASs had lower scores on the Star Excursion Balance Test (SEBT) (anterior direction) compared with those who did not.[8] Similarly, individuals with LAS demonstrated decreased dynamic balance scores compared with the healthy group, as reported in studies by Fraser *et al*,[29] Doherty *et al*[30] and Ko *et al*.[29–31] Furthermore, neuromuscular control issues and reduced ankle ROM in injured individuals may contribute to these dynamic balance deficits, as these are known to affect reach and stability in multiple planes.[30] In particular, the anterior direction of the YBT requires adequate dorsiflexion ROM. Studies have shown that limited dorsiflexion significantly affects performance in this direction, making it a potential measure for assessing ROM limitations.[32 33]

The second possible explanation is that the players had weaker dynamic balance before the injury. In the prospective cohort of Hartley *et al*, the anterior direction of the YBT was shown to be a significant risk factor in male athletes.[11] Similarly, Gribble *et al* found that low performance on the anterior reach direction of the SEBT significantly predicted ankle sprain injury in American high school and college football players.[8] Also, Attenborough *et al* reported that impaired a preseason dynamic postural balance significantly increased the risk of ankle sprains among netball players.[34] Taketomi *et al* also demonstrated prospectively decreased dynamic balance as a risk factor for LAS.[35] Under this assumption, it is likely that a balance deficit existed prior to the ankle injury and persisted throughout the rehabilitation period up to the time of our study. This might provide a theory for the development of CAI. The moderate effect sizes observed in the Y Balance measures suggest that these impairments are not only statistically significant but may also have practical implications for the performance and safety of athletes with a history of LAS.

Functional activity limitations

The FAAM scores further confirm the functional limitations experienced by athletes with a history of LAS. The significant reductions in both the activities of daily living and sports subscales of the FAAM indicate that these players experience persistent functional impairments that likely affect their ability to prevent reinjuries. Considering individual FAAM scores, our study revealed that 20% of athletes with a history of injury had moderate limitations (range 75%–78.57% scores) in their sport-related functions. For these athletes, tasks such as jumping, landing, starting and stopping, cutting/lateral movement were challenging (slight or moderate) at the time of the study. These tasks are fundamental to soccer, and limitations in performing them can reduce overall sports performance. At the same time, it is worth noting that the control group showed no limitations in these movement tasks (100% marked no problems). These findings are consistent with the study by,[15] which

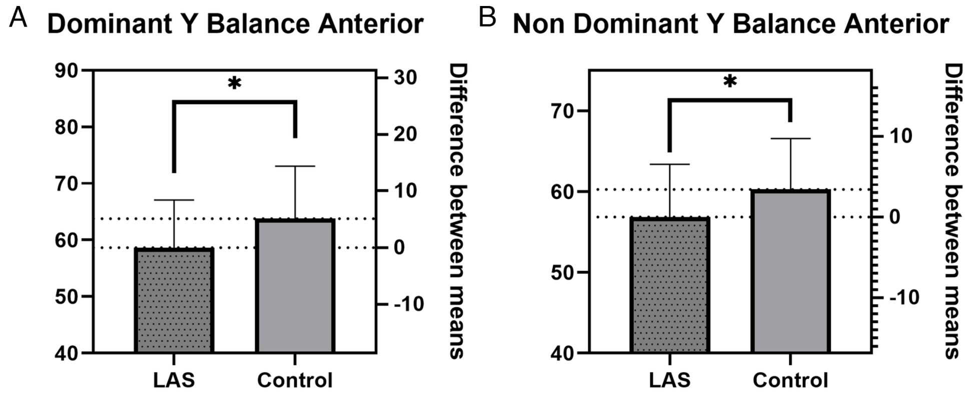

Figure 1 (A) Dominant Y Balance Anterior (cm) score between groups. (B) Non Dominant Y Balance Anterior (cm) score between groups. LAS, lateral ankle sprain. *p<0.05.

discussed how lack or inadequate rehabilitation of ankle injuries can lead to chronic functional limitations, as captured effectively by tools like the FAAM.[15] It is worth noting that all athletes in our study have gone through rehabilitation. On the other hand, an additional question about postinjury prevention exercises showed that none of these participants had performed them. Both FAAM subscales showed statistically significant differences between groups with moderate effect sizes in our study. However, FAAM scores did not exceed the minimal clinically important difference on average (6.9, 5.7 and 8 points for the ADL and 10, 12.3 and 9 points for sports subscale).[18] Given the established thresholds for FAAM, our results should be considered with caution.

Lack of significant differences in strength and mobility measures

Interestingly, while balance and functional activity measures revealed significant differences, strength and mobility tests did not show statistically significant differences between groups. The WBLT, SHT and HRT, as well as the measures of isometric strength (ankle plantarflexion and dorsiflexion, hip abduction), did not differ significantly between the groups. These findings suggest that the impact of LAS on strength and mobility might be less pronounced than its effects on balance and functional performance. It is partially consistent with a study by Fraser *et al*, where recreationally active individuals showed decreased strength in ankle muscles, including plantar flexion and inversion, except for dorsiflexion.[29] Friel *et al* pointed out that ipsilateral hip abductor weakness is commonly observed following inversion ankle sprains, which further exacerbates balance impairments and may contribute to the observed deficits in YBT performance.[9] In our study, despite differences in dynamic balance, there were no differences between groups or between limbs for isometric hip abductor strength. However, the participants in the Friel *et al* study did not receive postinjury rehabilitation, which may account for the weakened hip muscle strength.[9] It is possible that these players who have returned to sports training have recovered baseline strength and mobility, but that residual deficits in balance and functional activities persist. Chinn and Hertel[36] similarly noted that while strength deficits may recover with appropriate rehabilitation, balance and proprioceptive impairments often persist.[36] This distinction the importance of focusing on balance and proprioceptive training in rehabilitation to address deficits that may not be self-correcting through general strength training.[2] In particular, as professional athletes, our participants were likely to have undergone rehabilitation programmes aimed at restoring functional strength and mobility after LAS, which may explain the

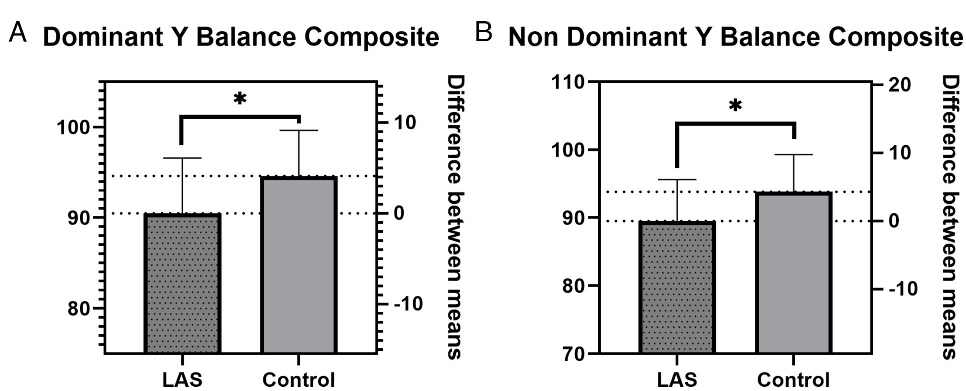

Figure 2 (A) Dominant Y Balance Composite (%) score between groups. (B) Non Dominant Y Balance Composite (%) score between groups. LAS, lateral ankle sprain. *p<0.05.

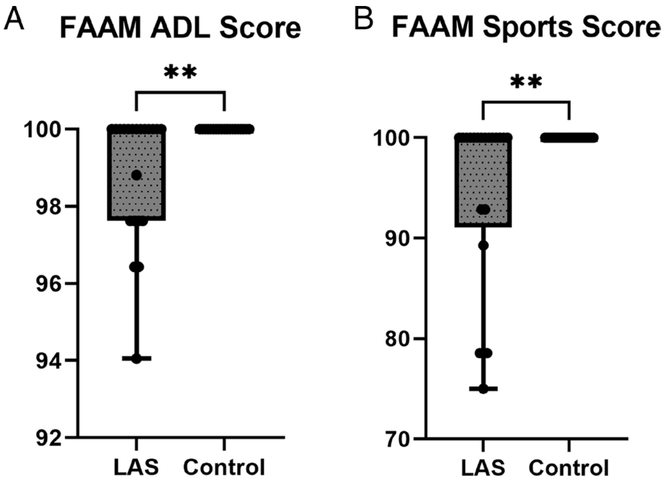

Figure 3 FAAM ADL (A) between groups. FAAM Sports Score (B) between groups. ADL, activities of daily living; FAAM, Foot and Ankle Ability Measure; LAS, lateral ankle sprain. **p<0.01.

lack of observable strength or mobility deficits. This divergence from some earlier studies could reflect the impact of sport-specific training and higher rehabilitation standards in professional settings, which may mitigate strength loss more effectively than recreational settings.[2] Additionally, previous studies, such as Friel *et al*, examined individuals without postinjury rehabilitation, which could explain the observed weaknesses in muscle strength in their sample that were not seen in ours.[9]

The SHT appears to be a particularly effective tool for evaluating postinjury LAS. This test assesses not only lower limb muscle strength, but also sensorimotor function while placing stress on the lateral aspect of the ankle and ligaments. A case–control study by Docherty *et al* found an association (moderate positive correlation) between SHT scores and the functional ankle instability index in college athletes.[37] The SHT as an assessment of sensorimotor function, which we can identify with dynamic postural control,[37] would appear to be the same as dynamic balance scores. Despite this, our study showed no significant differences in SHT between groups or between limbs within the LAS group. It is possible that the SHT lacks the sensitivity to detect subtle deficits unique to the LAS group, or that the rehabilitation protocols undertaken by our athletes were effective in restoring performance in areas such as jumping and strength. The HRT scores of participants in the study did not differ between groups. It is noteworthy that the scores were relatively high in comparison to other studies. For instance, in the Flore *et al* study, healthy men (non-athletes) achieved a score of 27.1±5.4 for the dominant limb.[38] In our study, soccer players (without a history of LAS) achieved a score of 41.6±9.4 for the same limb. Consequently, our findings support the notion that while strength and mobility can recover with adequate training, balance and functional performance may require more specialised, long-term interventions to reduce the risk of reinjury and optimise athletic performance.

Table 5 Difference analysis: injured versus non-injured leg in LAS group

Variables	Injury limb	Non-injured limb	MD±SE	95 % CI	P value	Effect size
WBLT (cm)	8.14±2.67	8.88±2.97	−0.7381±0.473	(−1.72 to 0.248)	0.134	d=−0.341
HRT (rep)	45.0±11.7	46.7±14.6	−2.00±1.84	(−8.50 to −4.00)	0.440	r=−0.253
Side Hop Test (points)	14.0±9.10	12.8±7.13	1.12±0.677	(−0.22 to 2.699)	0.098	r=0.450
Plantar Flexion Force (kg)	21.8±4.22	21.8±3.72	−0.0667±0.455	(−1.02 to 0.833)	0.467	d=−0.0320
Dorsiflexion Force (kg)	28.4±4.0	27.9±4.62	0.600±0.568	(−1.45 to 3.00)	0.529	r=0.209
Hip Abduction Force (kg)	17.9±3.52	18.1±3.12	−0.475±0.600	(−1.40 to 0.640)	0.434	r=−0.199
YBT Anterior (cm)	59.0±8.03	59.5±6.87	2.48±1.37	(−0.387 to 5.34)	0.086	d=0.394
YBT Posterolateral (cm)	101.0±8.62	102.00±8.55	−0.762±1.57	(−4.24 to 2.71)	0.652	d=−0.0998
YBT Posteromedial (cm)	101.2±8.40	98.2±10.5	2.50±2.44	(−3.00 to 9.00)	0.255	r=0.320
YBT Composite (cm)	90.8±5.48	89.2±6.6	2.32±0.930	(−1.30 to 5.98)	0.184	r=0.429

·Paired t-tests for normally distributed data and Wilcoxon signed-rank tests for non-normally distributed data.
d, Cohen's d; HRT, Heel Rise Test; LAS, lateral ankle sprain; MD, mean difference; MD ± SE, Mean Difference ± Standard Error; r, rank-order correlation coefficient; WBLT, Weight Bearing Lunge Test; YBT, Y Balance Test.

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Injured versus non-injured leg within the LAS group

When examining the LAS group, there were no significant differences between the injured leg compared with the non-injured leg. Overall, the lack of significant p values suggests that the functional performance of the injured limb was comparable to that of the non-injured limb across all tests. Similarly, a retrospective study by Denegar *et al* showed no differences in ankle DF ROM between the injured and healthy ankles.[39] However, the sample was small, consisting of female students as well, and the methods of the DF ROM assessment were different, hence comparison with our results is limited.[39] In our study, the fact that 100% of the athletes in our sample received full rehabilitation after LAS injury probably resulted in that there was no asymmetry between limbs.

Asymmetry in YBT results has been identified as a potential risk factor for injury in soccer players.[40 41] Specifically, YBT scores for the anterior direction in the Y-Balance test of more than 4 cm have been described as a cut-off point for injury risk.[42] In our study, the non-difference in YBT ANT scores between the injured and healthy limb was 2.5±1.4 but did not exceed the threshold of significance (p=0.086).

Clinical implications

The findings of this study support the need for targeted rehabilitation programmes that prioritise dynamic balance training in athletes recovering from LAS. Given the persistent balance deficits observed, even after the restoration of strength and mobility, clinicians should focus on addressing these impairments to reduce the risk of reinjury and enhance functional performance. Incorporating specialised balance exercises into postinjury protocols can improve outcomes and help prevent CAI in professional soccer players and other athletes.

Limitations and future directions

This study has several limitations that should be considered when interpreting the results. The final sample size was smaller than initially assumed and calculated for comparisons. Specifically, variables (FAAM, YBT) were underpowered due to the limited number of participants. With 80% power and a significance level of 5%, we would need approximately 64 participants per group for FAAM and 33 participants per group for YBT. This reduced power may limit the ability to detect potentially clinically relevant differences in these variables and increase the risk of type II errors. This limitation restricts the generalisability of our results to larger, more diverse populations, as our findings may not fully capture the variability within the broader population. Additionally, the case–control design of this study limits the ability to draw causal conclusions about the relationship between LAS and the observed functional impairments. Moreover, while this study focused on professional soccer players, the findings may not be generalisable to athletes in other sports or to amateur soccer players. Future studies should explore whether the observed impairments are consistent across different levels of play and different types of sports and focus on longitudinal studies with long-term impact.

CONCLUSION

Professional soccer players with a history of LAS may experience challenges in dynamic balance and functional performance compared with healthy individuals. Notably, no asymmetry was observed between the injured and non-injured legs. These findings underscore the potential benefit of targeted rehabilitation programmes that address specific balance and performance impairments to help reduce the risk of reinjury and enhance overall athletic performance.

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