

Prevalence of Proprioceptive Deficits in Football Players with Knee Ligament Injury

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ABSTRACT

Background: Proprioception is essential for joint stability and neuromuscular control, and its impairment following knee ligament injuries may increase the risk of re-injury in football players.

Methodology: This observational study included 70 elite football players post-surgical ACL, MCL, or PCL injuries. Participants were assessed after 8 weeks using the Modified Star Excursion Balance Test (mSEBT) and Joint Position Sense (JPS). Data were analyzed to determine prevalence and correlation of proprioceptive deficits.

Results: SEBT composite scores were lower in the affected limb (0.81 ± 0.10) compared to the normal limb (0.90 ± 0.07). JPS errors were higher in the affected limb ($7.98^\circ \pm 6.77$) than the normal limb ($3.32^\circ \pm 1.51$). A significant positive correlation was found between normal and affected limb SEBT scores ($r = 0.361$, $p = 0.002$), while no correlation was observed between SEBT and JPS.

Conclusion: Football players exhibited significant proprioceptive deficits post-injury. mSEBT and JPS assess distinct aspects of proprioception and should be used together for comprehensive rehabilitation.

Keywords: Proprioception, Knee ligament injury, mSEBT, Joint Position Sense, Football players

INTRODUCTION

Information from proprioception, the inability to precisely manage neuromuscular control, may result in a higher risk of re-injury and deficiencies in coordination when great performance is needed.¹ To adapt to the environment around us and act quickly in situations that change, we rely on signals from our moving bodies during daily tasks. Sensations originating in proprioceptors supply a large portion of this information regarding the position and movement of the limbs and trunk.² Together with compensatory hip and ankle adaptations, these findings suggest a tendency to avoid utilising the quadriceps.³ During landing, the lower extremities' functional purpose is to effectively absorb, disperse, and transmit vertical ground reaction force (VGRF).⁴

One of the main objectives of sports is to prevent injuries by identifying those who are more likely to get an injury. Evidence has recently surfaced that suggests SEBT is a highly repeatable medication and performance.⁵

SEBT performance may make it easier to assess individual performance and assist doctors in identifying athletes who may be at higher risk of injury if they depart from the average SEBT performance values of their team.⁶ Explanation of the conflicting

results among studies is that in addition to assessing balance, the SEBT also requires lower extremity strength, range of motion, and coordination, which may increase its sensitivity to predict injuries.⁷ Physical therapists frequently use the modified Star Excursion Balance Test (mSEBT) as a screening tool to identify dynamic balance deficiencies and assess improvement in dynamic balance in people who have participated in a preventive training program. The mSEBT assesses dynamic balance by having a subject balance on one leg while concurrently using the other leg to reach as far as they can in three different directions (anterior, posteromedial, and posterolateral).⁸ The mSEBT is a trustworthy measurement tool in previous research examining its reliability.⁸ Patients with a history of anterior cruciate ligament (ACL) tears do worse on the SEBT than controls.

Consequently, it seems that dynamic balance is linked to a higher risk of injury and that after an injury, dynamic balance changes that impair dynamic balance capacity.⁹ Cruciate ligaments play a crucial role in neurosensory and biomechanical function as part of the knee capsuloligamentous system. Due to the failure of the majority of previous primary ACL repair procedures, reconstruction has emerged as the recommended procedure.¹⁰ Numerous investigations have demonstrated that surgical restoration can partially restore the proprioceptive abnormalities present in knees with an ACL deficiency. The onset of knee arthritis has been linked to decreased proprioception.¹¹

Degenerative alterations in long-term follow-up are linked to injuries to the posterior cruciate ligament (PCL), which can cause cartilage loss, deterioration of position perception, and reduced proprioceptive function. Consequently, proprioceptive function recovery by mechanoreceptor regeneration, with significant afferent capabilities, is linked to PCL rebuilding for individuals with PCL insufficiency.¹² Poor results have been

linked to non-operative therapy. Nowadays, the main goals of treatment are either to repair the damaged structures, use grafts to rebuild the damaged structures, or do both. Compared to ligament reconstruction, two investigations have shown that isolated repair had greater rates of treatment failure.¹³ Due to the growing number of reconstruction procedures, including total knee arthroplasty and arthroscopic ligament repair, the proprioceptive functions of the anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) have been further studied. In particular, a great deal of research has been done on the PCL intraligamentous neuronal network, which controls neurosensory function in both humans and animals.¹⁴

The importance of functional problems like proprioception and compensating mechanisms in attaining post-operative stability has just now come to light.¹⁵ It is challenging to identify the aetiology of the proprioceptive loss because knee injuries involving ACL rupture frequently also harm menisci, collateral ligaments, and the cartilage of the femoral and tibial surfaces.¹⁶ For male professional football players, an anterior cruciate ligament (ACL) injury is a significant and occasionally career-threatening condition. While a professional athlete may choose non-surgical treatment, early ACL reconstruction (ACLR) is seen to be the best course of action.¹⁷ In order to restore knee stability and enable a return to football, reconstructive surgery is frequently carried out.¹⁸ In pivoting sports, ACL injuries frequently result in knee instability, and ACL reconstruction (ACL-R) is frequently advised.¹⁹

The neuromuscular control of the rebuilt knee may be significantly influenced by the activation of the hamstrings.²⁰ Proprioception seems to be crucial for preventing ACL injuries as well as for restoring full function following ACL surgery.²¹

Proprioception, often described as the "sixth sense," refers to the body's ability to perceive its position, movement, and spatial

orientation without relying on visual input. This neurosensory mechanism is mediated by mechanoreceptors located within joints, ligaments, muscles, and tendons, which transmit afferent signals to the central nervous system to facilitate coordinated movement and joint stability²²

Beyond the foundational understanding of proprioceptive mechanisms already established in the literature, emerging evidence suggests that the complex interplay between mechanoreceptor function and neuromuscular control extends to various clinical contexts. Research has demonstrated that proprioceptive training programs can enhance postural control and reduce injury risk in athletic populations.²³ Furthermore, advanced neuroimaging studies have revealed cortical reorganization following ligament injuries, indicating central nervous system adaptations that may contribute to persistent functional deficits even after successful surgical reconstruction.²⁴

The relationship between proprioceptive deficits and functional performance has been explored across different populations and injury types. Studies examining chronic ankle instability have shown parallels with knee ligament injuries in terms of sensorimotor impairments and compensatory movement strategies.²⁵ Additionally, age-related changes in proprioceptive acuity may interact with injury-related deficits, potentially compounding the challenges faced by athletes returning to high-level competition.²⁶

Recent investigations have also highlighted the importance of psychological factors in proprioceptive performance. Fear of re-injury and kinesiophobia have been associated with altered movement patterns and reduced proprioceptive confidence, suggesting that comprehensive rehabilitation must address both physical and psychological components.²⁷ Moreover, the timing of proprioceptive assessment during the rehabilitation continuum appears

critical, as deficits may manifest differently during early versus late recovery phases.²⁸

Despite advances in surgical techniques and rehabilitation protocols, the extent and clinical implications of persistent proprioceptive deficits in football players remain incompletely understood. Understanding the prevalence and magnitude of these deficits is essential for developing evidence-based rehabilitation protocols and return-to-play criteria that address not only structural stability but also neurosensory function, ultimately improving long-term outcomes and reducing the risk of re-injury in this high-risk athletic population.

MATERIALS & METHODS

This observational study aims to examine the extent of proprioceptive deficits in elite football players from Nashik who have undergone surgical treatment for knee ligament injuries, specifically involving the anterior cruciate ligament (ACL), medial collateral ligament (MCL), and posterior cruciate ligament (PCL). With a sample size of 70 participants selected through purposive sampling over a duration of six months, the study will be conducted at football training centers and physiotherapy or rehabilitation clinics. The primary objective is to determine the prevalence and severity of proprioceptive deficits, while the secondary objective is to explore the correlation between injury severity and proprioceptive impairment. Eligible participants will include male and female football players aged 18 years and above who have undergone surgical intervention and will be assessed after a minimum of eight weeks post-surgery. Players treated conservatively, those under 18 years of age, individuals with avulsion fractures, or those with other knee-related conditions will be excluded. Data collection will be carried out using standardized documentation materials such as structured data collection forms, informed consent forms in English and Marathi, writing tools, and coded identification labels to maintain

confidentiality. The assessment will be conducted in a controlled environment requiring a minimum 4 × 4-meter clear space with a flat, non-slip surface and adequate lighting to ensure accuracy and consistency during proprioceptive testing procedures.

OUTCOME MEASURES

Modified Star Excursion Balance Test (mSEBT):

A dynamic balance test used to assess proprioception, postural control, neuromuscular coordination, and lower limb function. It requires integration of visual, vestibular, and somatosensory inputs to maintain single-leg stability while reaching in multiple directions.

Joint Position Sense (JPS):

A measure of proprioception that evaluates the ability to accurately perceive and reproduce joint angles. It reflects afferent input from mechanoreceptors and indicates neuromuscular control and joint stability. Deficits suggest impaired proprioceptive function and increased injury risk.

Procedure

The approval from the institutional ethical committee, permission was obtained from football clubs and teams to assess their players. Participants were informed about the study in their preferred language, and written informed consent was obtained after clearly explaining all procedures. The Modified Star Excursion Balance Test (mSEBT) was conducted by preparing four strips of athletic tape arranged in a '+' and 'x' pattern to form an eight-direction star with 45° angles. Participants maintained a single-leg stance on the testing limb while reaching with the contralateral leg in anterior, posteromedial, posterolateral, and composite directions, ensuring stability throughout. Reach distances were measured, compared between injured and non-injured limbs, and analyzed using normalized scores calculated as the mean of three trials in a

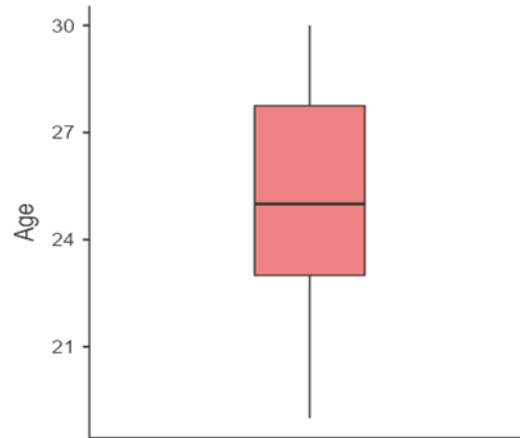
direction divided by limb length and multiplied by 100. Normal reference ranges included anterior (61.6–69.4%), posterolateral (83.9–96.6%), and posteromedial (99.2–113.1%). Additionally, Joint Position Sense (JPS) was assessed by positioning the participant in sitting or lying with the knee at a target angle (e.g., 30° flexion). With eyes closed or blindfolded to eliminate visual input, participants attempted to actively reproduce the given joint position. The difference between the actual and reproduced angle was recorded, with greater discrepancies indicating reduced proprioceptive accuracy and impaired joint position sense.

Statistical Analysis

Spearman's correlation analysis showed a significant positive relationship between SEBT composite scores of the unaffected and affected limbs ($r = 0.361$, $p = 0.002$), indicating that better dynamic balance in the uninjured limb was associated with relatively improved performance in the injured limb, possibly due to neuromuscular adaptation or cross-education effects mediated by the central nervous system. However, no significant correlation was found between SEBT and JPS scores or between JPS values of affected and unaffected limbs, suggesting that these measures assess different components of proprioception. While SEBT reflects dynamic balance and functional neuromuscular control involving multiple sensory systems, JPS evaluates static proprioceptive accuracy based on joint position replication. Therefore, dynamic and static proprioception appear to function independently, highlighting the importance of using both SEBT and JPS as complementary tools for comprehensive assessment and targeted rehabilitation of sensorimotor function

RESULT

Age Distribution of Participants

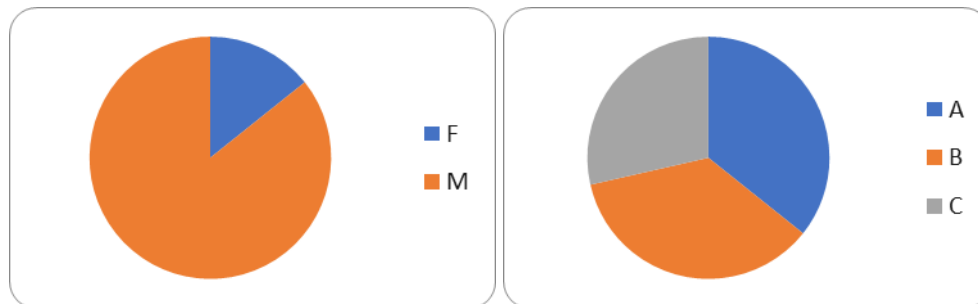


Descriptives						
	N	Mean	Median	SD	Minimum	Maximum
Age	70	24.9	25	2.87	19	30

The study included a total of 70 football players, with ages ranging from 19 to 30 years. The mean age was 24.9 ± 2.87 years, with a median of 25 years. The age distribution boxplot showed a symmetrical spread with few mild lower-end outliers, suggesting a homogeneous sample of young adult football players. This relative uniformity in age helps minimize confounding effects when assessing proprioceptive outcomes.

Star Excursion Balance Test (SEBT) composite scores revealed higher values in the normal leg (mean = 0.90 ± 0.073) compared to the affected leg (mean = 0.81 ± 0.109). Joint Position Sense (JPS) flexion errors were lower in the normal leg (mean = $3.32^\circ \pm 1.51$) than in the affected leg (mean = $7.98^\circ \pm 6.77$), suggesting impaired proprioceptive accuracy post-injury.

Gender and Group Distribution



Frequencies		
Frequencies of Gender		
Gender	Counts	% of Total
F	10	14.30%
M	60	85.70%

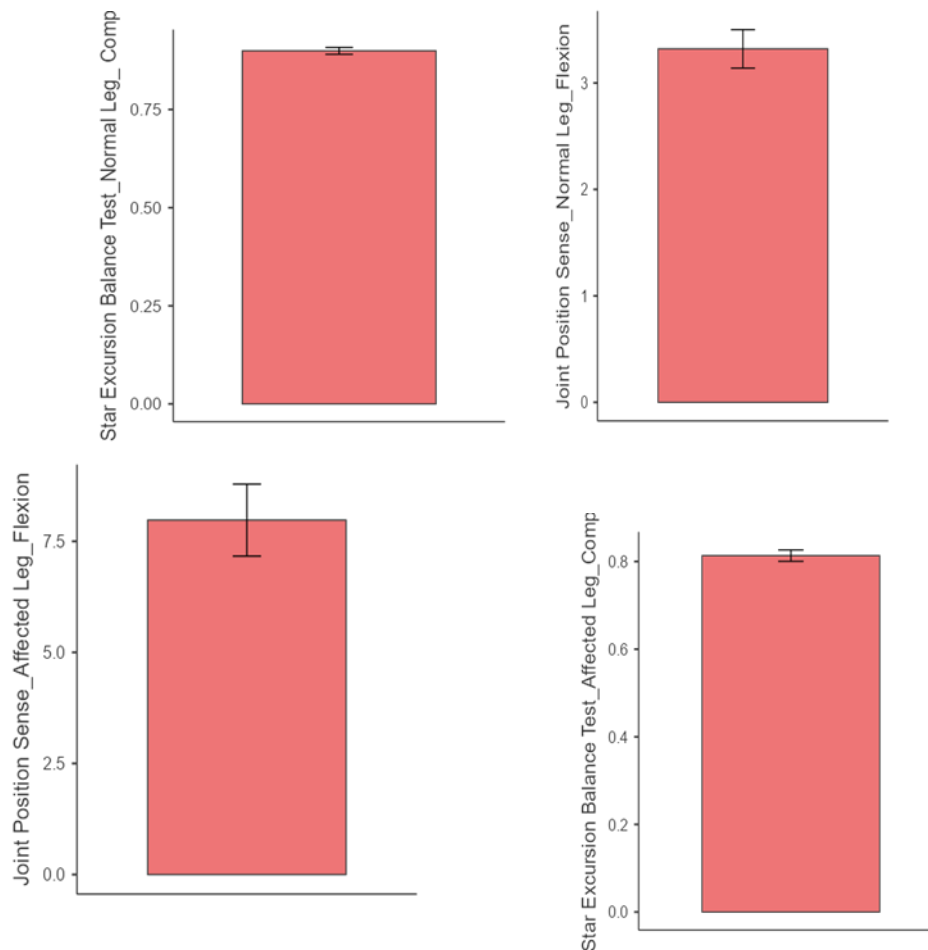
Frequencies of Group		
Group	Counts	% of Total
A	25	35.70%
B	25	35.70%
C	20	28.60%

The gender distribution revealed a clear male predominance, with 60 male participants (85.7%) and 10 female participants (14.3%). This reflects the demographics of competitive football, though female inclusion added valuable diversity.

The group allocation was nearly balanced: Group A (25 players, 35.7%), Group B (25 players, 35.7%), and Group C

(20 players, 28.6%). Clinically, while male dominance aligns with the sport's participation trends, the relatively small number of female players limits gender-based generalizability.

SEBT and JPS Overall Results



Descriptives						
	N	Mean	Median	SD	Minimum	Maximum
Star Excursion Balance Test_Normal Leg_Comp	70	0.9	0.906	0.0737	0.74	1.06
Star Excursion Balance Test_Affected Leg_Comp	70	0.813	0.806	0.1087	0.438	1.1
Joint Position Sense_Normal Leg_Flexion	70	3.32	3.315	1.5111	1	8
Joint Position Sense_Affected Leg_Flexion	70	7.978	6.315	6.7767	1.67	53

The Star Excursion Balance Test (SEBT) composite scores were significantly higher in the normal leg (0.90 ± 0.073 , range 0.74–1.06) compared to the affected leg (0.81 ± 0.109 , range 0.438–1.10). This indicates

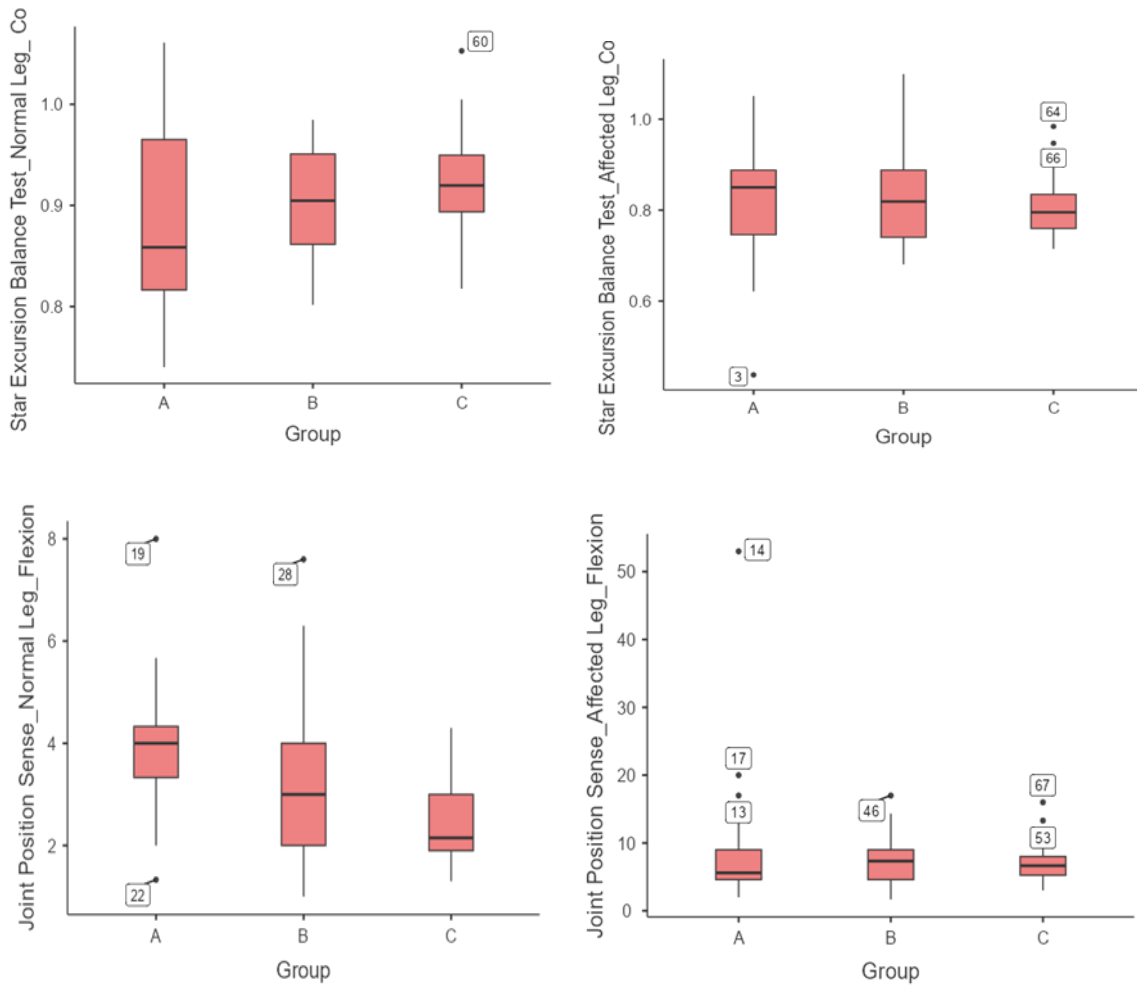
compromised dynamic balance in the injured limb.

The Joint Position Sense (JPS) flexion error also highlighted proprioceptive deficits. The normal leg demonstrated lower error values

($3.32^\circ \pm 1.51$, range 1–8), whereas the affected leg showed markedly higher errors ($7.98^\circ \pm 6.77$, range 1.67–53). The large variability and extreme outliers in the affected leg confirm considerable heterogeneity in proprioceptive loss, with some athletes exhibiting profound impairments.

Together, SEBT and JPS results confirm that proprioceptive deficits exist in the affected limb across both dynamic balance and joint position domains.

Group-wise SEBT and JPS Comparison

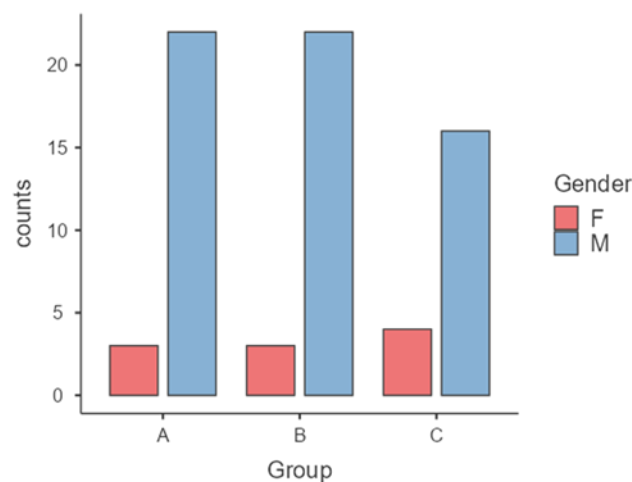


Descriptives							
	Group	N	Mean	Median	SD	Minimum	Maximum
Star Excursion Balance Test_Normal Leg_Comp	A	25	0.883	0.859	0.095	0.74	1.061
	B	25	0.9	0.905	0.0576	0.802	0.985
	C	20	0.92	0.92	0.0581	0.818	1.053
Star Excursion Balance Test_Affected Leg_Comp	A	25	0.813	0.85	0.1328	0.438	1.051
	B	25	0.818	0.819	0.1113	0.681	1.099
	C	20	0.809	0.795	0.07	0.715	0.984
Joint Position Sense_Normal Leg_Flexion	A	25	3.984	4	1.3804	1.33	8
	B	25	3.348	3	1.7315	1	7.6
	C	20	2.457	2.15	0.856	1.3	4.3
Joint Position Sense_Affected Leg_Flexion	A	25	9.091	5.6	10.1805	2	53
	B	25	7.638	7.33	4.2253	1.67	17
	C	20	7.011	6.65	3.2465	3	16

Group analysis revealed distinct patterns. For SEBT (Normal Leg), Group C showed the best performance (0.92 ± 0.058), followed by Group B (0.90 ± 0.057) and Group A (0.88 ± 0.095). For SEBT (Affected Leg), all groups demonstrated reductions compared to their normal legs, with Group A showing the widest variability (0.81 ± 0.133) and several low outliers. In JPS (Normal Leg), Group A showed the highest errors ($3.98^\circ \pm 1.38$), Group B was moderate (3.35 ± 1.73), and Group C the

lowest (2.46 ± 0.85). In JPS (Affected Leg), Group A again had the highest mean error ($9.91^\circ \pm 10.18$) with extreme outliers up to 53° , while Groups B (7.63 ± 4.23) and C (7.01 ± 3.24) showed lower, but still elevated, errors. Overall, Group A consistently exhibited the poorest proprioceptive performance, while Group C demonstrated relatively preserved function.

Group × Gender Distribution



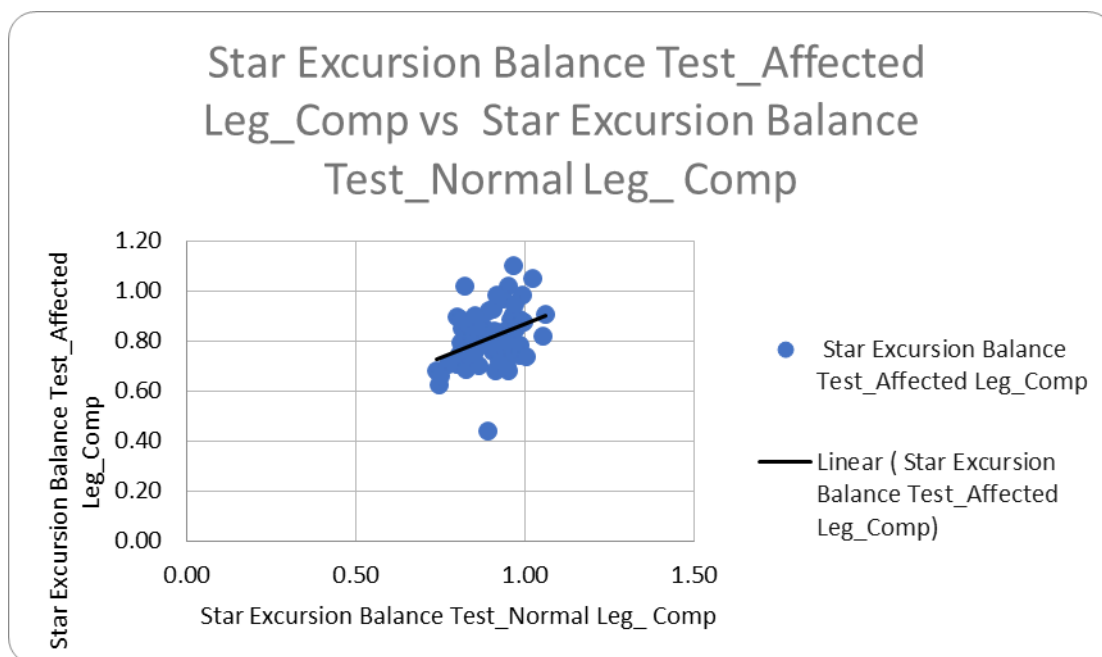
Frequencies			
Frequencies of Group			
Group	Gender	Counts	% of Total
A	F	3	4.30%
	M	22	31.40%
B	F	3	4.30%
	M	22	31.40%
C	F	4	5.70%
	M	16	22.90%

- Across all groups, males predominated.
- Group A: 22 males (31.4%), 3 females (4.3%)
 - Group B: 22 males (31.4%), 3 females (4.3%)
 - Group C: 16 males (22.9%), 4 females (5.7%)

The proportional balance of males across groups supports valid inter-group

comparisons. However, the small female sample limits meaningful subgroup gender analyses. Still, female representation, although minor, broadens the scope of the study beyond male-only football populations.

Correlation Analysis



Correlation			
Variable Pair	Spearman's ρ	p-value	Significance
SEBT Composite (Normal Leg) ↔ SEBT Composite (Affected Leg)	0.361	0.002	p < 0.01
SEBT Composite (Normal Leg) ↔ JPS Flexion Error (Normal Leg)	0.124	0.308	n.s.
SEBT Composite (Normal Leg) ↔ JPS Flexion Error (Affected Leg)	-0.069	0.568	n.s.
SEBT Composite (Affected Leg) ↔ JPS Flexion Error (Normal Leg)	0.069	0.568	n.s.
SEBT Composite (Affected Leg) ↔ JPS Flexion Error (Affected Leg)	0.035	0.776	n.s.
JPS Flexion Error (Normal Leg) ↔ JPS Flexion Error (Affected Leg)	-0.052	0.666	n.s.

DISCUSSION

This study's findings clearly identify proprioceptive deficits in the affected leg among football players with knee ligament injuries. The SEBT results confirm a lack of dynamic balance on the injury-associated limb, and JPS results indicate significant errors in joint position reproduction, suggesting limited sensory feedback from mechanoreceptors within the knee joint. These findings are consistent with available literature, which suggests that ligament injury interrupts afferent feedback and thus disturbs neuromuscular control. Group comparisons highlighted that although all groups displayed deficits in the affected limb, the severity varied.

Group A showed the worst outcomes with the highest variance in both SEBT and JPS values; inferring that they experienced the greatest proprioceptive errors. The wide variance may be explained through rehabilitation advancement, injury and/or ligament severity, and several other factors linked to recovery. Group C had relatively intact proprioception, which supports that these athletes either recovered quickly or maintained a better level of proprioception at baseline. The correlation analysis does provide additional insight into these relationships as players with better proprioceptive control in their normal limb, had relatively better outcome in their injured limb. However, there were no significant correlations between SEBT and JPS which

suggests that these two metrics measure different proprioceptive domains. Therefore, the dynamic identified through balance (SEBT) and the joint position accuracy (JPS) are indeed complementary and should be incorporated into clinical assessments and rehabilitation protocol.

From a clinical perspective, the need for specific proprioceptive retraining following ligament injury during physiotherapy management is reinforced by these findings. Stabilization exercises aimed at restoring balance control, joint position sense and neuromuscular re-education are critical for the achievement of active functional stability and the reduction of the risk of re-injury. The wide range of variability in the affected leg JPS, highlights the need for personalized rehabilitation programs.

Strengths of this study include the sufficient sample size and group proportions which helped ensure meaningful subgroup analysis. However, the male sample predominance (85.7%) has implications for generalization of the findings towards female athletes. Additionally, as level of injury severity and rehabilitation history varied among participants, this may have contributed to the differences observed among groups.

In this study, proprioceptive deficiencies in football players with knee ligament injuries were assessed through the use of the Star Excursion Balance Test (SEBT/mSEBT) and Joint Position Sense (JPS). The data demonstrated decreased SEBT composite scores, and JPS errors were significantly greater in the involved limb compared to the contralateral normal limb. These findings support that proprioceptors are an enduring effect of cruciate ligament injury and result from the rupture of neurosensory mechanisms necessary for maintaining dynamic stability and motor performance.

Proprioceptive deficits following cruciate ligament injury

Following cruciate ligament injury, proprioceptive deficits will arise. The early studies have shown that proprioception is

impaired in knees deficient in a cruciate ligament. Among the first studies to confirm that knees without a posterior cruciate ligament (PCL) had measurable proprioceptive deficits, were performed by Safran et al.¹ The researchers looked specifically during mid-range flexion, where ligamentous feedback is most important. Yoon et al.² also conducted a meta-analysis on proprioception outcomes post-PCL reconstruction and found significant proportional errors in reconstructions (both TTDP and JPS) compared to contralateral intact knees.

SEBT and dynamic postural control

The Star Excursion Balance Test (SEBT) has become a prevalent objective measure of dynamic balance and proprioception. Plisky et al.⁵ determined that athletes with anterior reach asymmetry greater than 4cm or composite reach scores less than 89.6% of limb length had an increased risk of injury. This association was further supported by Butler et al.⁶ who performed a SEBT study in collegiate football players, and reported that athletes with poor SEBT scores had a 3.5 times increased risk of lower extremity injury as part of the intervention. In agreement with the previously discussed studies, the present study found lower SEBT scores in the injured limb of football players, indicating that the SEBT is sensitive to proprioceptive deficits following ligament injury. Stiffler et al.⁷ also discussed that SEBT performance may be variegated among sports, gender, and level of competition, and therefore it is prudent to have normative data for sport specific. Due to the lack of normative data for Indian football players, the current data is an important early first step.

Summary

This study confirms that football players with knee ligament injuries experience persistent proprioceptive deficits, reflected in reduced SEBT performance and increased JPS error. These findings align with international literature demonstrating

that cruciate ligament injuries disrupt mechanoreceptor function and neurosensory pathways, leading to impaired stability even after reconstruction. Clinically, SEBT and JPS should be integrated into assessment and monitoring, and rehabilitation should prioritize proprioceptive retraining to reduce reinjury risk. Emerging surgical techniques that preserve ligament remnants may further enhance proprioceptive recovery and improve long-term outcomes.

CONCLUSION

This study confirms significant proprioceptive deficits in the affected limbs of football players with knee ligament injuries. The findings highlight reduced SEBT reach distances and increased JPS flexion errors, with Group A showing the most severe impairments. The significant correlation between SEBT performance in normal and affected limbs suggests a link in balance ability, but the lack of association with JPS underscores the need for multidimensional assessment. Overall, these results emphasize the critical role of proprioceptive and balance retraining in post-injury rehabilitation programs.

Declaration by Authors

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Conflict of Interest: The authors declare no conflict of interest.

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