Inventum Biologicum: *An International Journal of Biological Research*
2025, Vol. 5, Issue 3, pp. 36-43

Inventum Biologicum

Journal homepage: www.journals.worldbiologica.com/ib

Research paper

The Effects of Core Stabilization Exercises Versus Plyometrics Along With Proprioceptive Training on Strength & Stability in Recreational Athletes With Non-Contact Anterior Cruciate Ligament Injury

Nitish [a], **Sharda Sharma** * [b], **Shama Praveen** [c], **Niraj Kumar** [d]

[a] *Researcher, Physiotherapy Department, Shri Guru Ram Rai School of Paramedical & Allied Health Sciences, Shri Guru Ram Rai University, Dehradun, Uttarakhand, India*
[b] *Ph. D. Scholar , MPT, Associate Professor, Physiotherapy Department, Shri Guru Ram Rai School of Paramedical & Allied Health Sciences, Shri Guru Ram Rai University, Dehradun, Uttarakhand, India*
[c] *Assistant Professor, Department of Physiotherapy, Shri Guru Ram Rai School of Paramedical & Allied Health Sciences, SGRRU University, Dehradun, Uttarakhand, India*
[d] *Ph. D. (Physiotherapy), MPT, MHA, Physiotherapy Department, Shri Guru Ram Rai School of Paramedical & Allied Health Sciences, Shri Guru Ram Rai University, Dehradun, Uttarakhand, India*

ARTICLE INFO

Keywords

Anterior Cruciate Ligament Injuries

Exercise Therapy
Proprioception
Rehabilitation
Plyometric Exercise
Physical Therapy Modalities
Postural Balance
Pain Measurement
Muscle Strength

DOI
10.5281/ib-2070425

***Corresponding author**
Sharda Sharma

✉ **Email**
shardasharma.physio@gmail.com

ABSTRACT

Background: Non-contact anterior cruciate ligament (ACL) injuries are common among recreational athletes and often lead to deficits in strength, dynamic balance, and joint proprioception. Core Stabilization Exercises (CSE) and Plyometric Training, both integrated with Proprioceptive Training, are established rehabilitation strategies; however, their comparative effectiveness requires further exploration.
Aim: The aim of the study was to assess the effects of 8 weeks of core stabilization exercises and plyometrics along with proprioceptive training on the strength & stability in recreational athletes with non-contact anterior cruciate ligament injuries.
Methods: Thirty recreational athletes aged 18–45 years with chronic non-contact ACL injuries were purposively sampled and divided into two groups. Group A received CSE with proprioceptive input, while Group B underwent Plyometric Training with proprioceptive input. Interventions were administered thrice weekly for eight weeks. Outcome measures included McGill's Core Muscle Endurance Test (CMET), Star Excursion Balance Test (SEBT), and Numeric Pain Rating Scale (NPRS), recorded at baseline, 4th week, and 8th week. Data were analyzed using repeated measures ANOVA and independent t-tests.
Results: Both groups demonstrated statistically significant improvements ($p < 0.05$) in all outcome measures. However, Group B showed superior gains in core endurance, balance, and pain reduction compared to Group A, with significant between-group differences ($p < 0.05$).
Conclusion: Plyometric Training combined with Proprioceptive Training proved more effective than Core Stabilization Exercises in improving functional outcomes in individuals with ACL injuries. These findings support incorporating dynamic, neuromuscular-focused protocols for enhanced rehabilitation.

1. Introduction

The anterior cruciate ligament (ACL) is an important component of the knee joint, withstands rotational loads and anterior tibial translation. It is among the most commonly damaged structures during sports or high-impact activities. [1]

Over 70% of ACL injuries happen in noncontact circumstances, and these injuries are typically caused by deficient control, which positions the athlete's knee joint in a "at-risk" alignment.

Specifically, the ability to stabilize the core is crucial during athletic activities, as it offers a solid base for the movement of the limbs. The core muscles, which encompass those in the trunk and pelvis, tend to activate prior to the main movements of the limbs to ensure stability for further mobility. Hence, maintaining core stability is essential and has gained significant attention in sports related to injury rehabilitation. Since core stability is linked to lower extremity injuries, various core strengthening methods have been extensively utilized in both injury prevention and recovery. Research has previously indicated that enhancing core stability might help decrease the likelihood of ACL injuries. [2]

Plyometrics was originally referred to as the “Stretch Shortening Cycle” or “Jump Training,” this method was introduced by Mr. Yuri Verkhoshansky, the coach of the Russian national jump team.

The term “Plyometrics” was introduced by Mr. Fred Wilt, a former athlete and coach in American track and field. It is derived from a Greek term, “Pliometric,” where “Plio/Plythine” translates to more/increase, and “Metric” means measurement. Thus, it signifies “to enhance the measurement.”

Plyometric exercises involve an eccentric contraction, where the muscle is fully extended right before it performs a concentric contraction. The speed at which the muscle transitions from an eccentric to a concentric contraction is key to an athlete's power output. The aim of plyometric training is to enhance the nervous system's response speed to muscle lengthening and to improve the muscle's capacity to shorten quickly with maximal force.[3]

Proprioception refers to the individual's perception of knee stability and is crucial for functional enhancement. The anterior cruciate ligament serves as a vital sensory organ that provides proprioception and triggers protective muscle reflexes, contributing to stabilization. Engaging in proprioceptive training can aid in the restoration of the knee's proprioceptive feedback system and improve its stability. Throughout the training process, the central nervous system coordinates proprioception signals coming from the limbs, trunk, and neck, as well as sensory information from the vestibular and visual systems, to uphold joint stability and enhance motor performance. Currently, proprioceptive training has been recognized globally and is extensively implemented for individuals undergoing anterior cruciate ligament reconstruction. [4]

Core stability refers to the ability to control the position and motion of the trunk over the pelvis and legs to effectively transfer loads during functional movements. Inadequate core stability can lead to compensatory movements, increasing the risk of non-contact ACL injuries. Studies have shown that poor core stability, weak hip abduction strength, and increased knee valgus contribute to ACL injury risk in young athletes. [5]

Core stability exercises engage muscles like the gluteus medius, gluteus maximus, and lumbar multifidus, which are crucial for maintaining proper alignment and movement patterns. Enhancing core endurance and strength can improve knee kinematics and reduce the risk of ACL injuries. [5,6]

Plyometric training involves explosive movements that improve power and rate of force development, essential for athletic performance. Following ACLR, plyometric training thought to be a crucial part of the functional recovery process. For a long time, plyometric training has been utilized to enhance athletes' explosive performance in sports and is considered a highly effective training approach because of its extensive neuromuscular and motor control advantages. Specifically, research has indicated that plyometric training is more effective than conventional resistance training for improving explosive performance in the lower limbs, as well as for producing increases in maximal strength and various sports performance elements, such as speed in linear and multidirectional movements. [7]

In a plyometric exercise, a muscle is stretched quickly (eccentric movement) and then the same muscle and connective tissue are shortened (concentric action). More force can be generated by a concentric movement alone when the muscle's stored elastic energy is consumed. When combined with a periodized strength-training program, plyometric exercise has been demonstrated to enhance vertical jump performance, acceleration, leg strength, muscle power, joint awareness, and proprioception in general. Typically, plyometric exercises require explosive stops, starts, and direction changes. These motions are elements that can help in agility development.[8]

Proprioceptive training focuses on enhancing the body's ability to sense its position in space, which is vital for joint stability and injury prevention. Together, these training modalities can restore neuromuscular function and movement quality in athletes recovering from ACL injuries.

Research indicates that incorporating plyometric exercises into rehabilitation programs can enhance lower limb strength, power, and sports performance variables, such as jump height and movement speed. Additionally, proprioceptive training improves balance and coordination, which are critical for preventing re-injury. [7]

While both Core stabilization exercises and Proprioceptive training have demonstrated benefits in ACL rehabilitation, their comparative effectiveness in recreational athletes remains underexplored. Core stability exercises may offer advantages in improving trunk control and reducing compensatory movements, whereas plyometric and proprioceptive training may be more effective in enhancing explosive strength and dynamic stability.

A study found that exercise programs including core stability exercises reduced the incidence of knee injuries by 46% in men and 65% in women. However, the integration of plyometric and proprioceptive training into rehabilitation programs has also shown promising results in restoring neuromuscular function and improving movement quality. [5,7]

The study aims to compare the effectiveness of two different rehabilitation approaches, Core Stabilization Exercises (CSE) and Plyometric Training along with Proprioceptive Training on improving strength and stability in recreational athletes suffering from non-contact ACL injuries.

2. Materials and Methods

Sample Size (N): 30, Sample size was calculated using G*Power version 3.1.9.2. at effect size=0.37, Power 0.95, and alpha value at 0.05
Sampling Method: Purposive Sampling
Study Design: A comparative experimental study.
Study Setting: SGRRU Campus, Physiotherapy OPD SMIH Dehradun (Uttarakhand).
Study Duration: Feb 2025 – July2025.
Study Participants: The study was performed on recreational athletes with non-contact ACL injury.
Study Groups: participants were divided into two groups: group A & group B.
Inclusion Criteria: Participants with age group between 18-45 years, Both males and females., Participants who were recreational athletes, Participants with non-contact ACL injury of 3 months or more, Subjects who were willing to participate in the study.
Exclusion Criteria: Participants with 0-3 months of ACL injury, Participants with fracture of lower extremities, Participants with any neurological deficit, Participant with major strength deficiencies, where the individual cannot even lift the torso from a forward flexed position to a neutral position, Any sensory disturbance near treating area.
Intervention: *Group A:* - Participants in this group were engaged in core stabilization exercises along with Proprioceptive training. Application of Core stabilization exercises, the program includes 5 exercises: Back extension, Supine pelvic tilt, Front-plank, Back bridge (Glute bridge), Quadruped exercise.
Group B: - Participants in this group were engaged in Plyometrics along with Proprioceptive training. Application of Plyometric exercises, the program includes 5 exercises: Ankle hops, Bilateral squat jumps, Lateral jumping, Diagonal jumping, Split squat jumps.

Participants attended three alternate days in a week for eight weeks of their intervention. To improve strength & stability, both groups followed their exercise programs and participate in structured warm-up and cool-down sessions.
Treatment Duration: 45 minutes session for 3 alternate days in a week for 8 weeks.
Outcome Measures: McGill's Core Muscle Endurance Test (CMET), Star Excursion Balance Test (SEBT), Numeric Pain Rating Scale (NPRS)
Procedure: 30 recreational athletes with non-contact ACl injury were selected and divided in two groups using the method of purposive convenience sampling, before any testing, the subjects were given a thorough explanation of the process and an informed consent form to be filled out. The study involved the participants who met the inclusion and exclusion criteria. Outcome measures were done for patient's pre and post treatment including McGill's core muscle endurance test (CMET), Star excursion balance test (SEBT) and NPRS then interventions will be given to patients. Both the group undergone the intervention procedure and data was collected at the baseline,4th week and last day of 8th week. Following a basic evaluation, each study participant was randomly allocated to one of two groups (both experimental groups): Group A: Core stabilization exercises with proprioceptive training, Group B: Plyometrics with proprioceptive training. Statistical analysis was carried out physically as well as with statistical software SPSS 23 version and Microsoft word, Excel has been used to generate graphs table etc.

3. Results

3.1 Group-A Analysis

Statistical software SPSS 23 version was used for analysis the data. To analyze the difference within group one way ANOVA test was used.

Table 1 Comparison within intervention showing Mean ±SD of CMET at 0-week, 4th week and 8th week measurement

To Analysis the difference within CMET scale in Group A:

Duration Group A	Mean ±SD	F-value	P-Value	Result
0 Week	61.3 ± 9.76	5.361	0.008	Significant
4th week	63.13 ± 9.438			
8th week	67.80 ± 8.059			

CMET scores at 0, 4, and 8 weeks were 61.3 ± 9.76, 63.13 ± 9.44, and 67.80 ± 8.06, respectively. One-way ANOVA revealed a statistically significant difference across time points ($p < 0.05$), indicating a meaningful improvement in core endurance. These results support the alternative hypothesis (H1) and reject the null hypothesis (H0).

Table 2 Comparison within intervention showing Mean ±SD of SEBT L 0-week, 4th week and 8th week measurement

To Analysis the difference within SEBT L score in Group A

Duration Group A	Mean ±SD	F-value	P-Value	Result
0 Week	89.133 ± 2.89	41.387	0.0001	Significant
4th week	92.86 ± 2.95			
8th week	98.95 ±3.10			

SEBT Left scores at 0, 4, and 8 weeks were 89.13 ± 2.89, 92.86 ± 2.95, and 98.95 ± 3.10, respectively. One-way ANOVA showed a statistically significant improvement over time ($\boldsymbol{p} < 0.05$), indicating enhanced dynamic balance. These findings support the alternative hypothesis (H1) and reject the null hypothesis (H0)

Table 3 Comparison within intervention showing Mean ±SD of SEBT R score 0-week, 4th week and 8th week measurement

To Analysis the difference within SEBT R score in Group A

Duration Group A	Mean ±SD	F-value	P-Value	Result
0 Week	87.90 ± 3.40	16.758	0.0001	Significant
4th week	90.77 ± 3.59			
8th week	95.32 ± 3.60			

SEBT Right scores at 0, 4, and 8 weeks were 87.90 ± 3.40, 90.77 ± 3.59, and 95.32 ± 3.60, respectively. One-way ANOVA indicated a statistically significant improvement across time points ($p < 0.05$), reflecting enhanced dynamic balance. These results support the alternative hypothesis (H1) and reject the null hypothesis (H0).

Table 4 Comparison within intervention showing Mean ±SD of NPRS SCALE 0-week, 4th week and 8th week measurement

To Analysis the difference within NPRS in Group A

Duration Group A	Mean ±SD	F-value	P-Value	Result
0 Week	1.53 ± 1.06	4.075	0.024	Significant
4th week	0.866 ± 0.639			
8th week	0.733 ± 0.703			

NPRS scores decreased from 1.53 ± 1.06 at baseline to 0.866 ± 0.639 at 4 weeks and 0.733 ± 0.703 at 8 weeks. One-way ANOVA showed a statistically significant reduction in pain over time ($p < 0.05$), supporting the alternative hypothesis (H1) and rejecting the null hypothesis (H0).

3.2 Group- B Analysis

Statistical software SPSS 23 version was used for analysis the data. To analyze the difference within groups one way ANOVA test was used.

Table 5 Comparison within intervention showing Mean ±SD of CMET 0-week, 4th week and 8th week measurement

To Analysis the difference within CMET score in Group B

Duration Group A	Mean ±SD	F-value	P-Value	Result
0 Week	59.40± 5.70	6.415	0.004	Significant
4th week	63.26 ± 6.29			
8th week	69.86 ± 8.33			

CMET scores improved from 59.40 ± 5.70 at baseline to 63.26 ± 6.29 at 4 weeks and 69.86 ± 8.33 at 8 weeks. One-way ANOVA revealed a statistically significant increase in core muscle endurance over time ($p < 0.05$), supporting the alternative hypothesis (H1) and rejecting the null hypothesis (H0).

Table 6 Comparison within intervention showing Mean ±SD of SEBT L 0-week, 4th week and 8th week measurement

To Analysis the difference within SEBT L score in Group B

Duration Group A	Mean ±SD	F-value	P-Value	Result
0 Week	89.96± 3.432	3.488	0.040	Significant
4th week	93.933 ± 3.32			
8th week	99.72 ± 3.41			

SEBT-L scores improved from 89.96 ± 3.43 at baseline to 93.93 ± 3.32 at 4 weeks and 99.72 ± 3.41 at 8 weeks. One-way ANOVA indicated a statistically significant improvement in balance over time ($p < 0.05$), supporting the alternative hypothesis (H1) and rejecting the null hypothesis (H0).

Table 7 Comparison within intervention showing Mean ±SD of SEBT R score 0-week, 4th week and 8th week measurement

To Analysis the difference within SEBT R score in Group B

Duration Group A	Mean ±SD	F-value	P-Value	Result
0 week	88.75 ± 3.54	26.040	0.0001	Significant
4th week	93.78 ± 4.18			
8th week	99.26 ± 4.20			

SEBT-R scores increased from 88.75 ± 3.54 at baseline to 93.78 ± 4.18 at 4 weeks and 99.26 ± 4.20 at 8 weeks. One-way ANOVA showed a statistically significant improvement over time ($p < 0.05$), indicating enhanced dynamic balance and supporting the alternative hypothesis (H1).

Table 8 Comparison within intervention showing Mean ±SD of NPRS 0-week, 4th week and 8th week

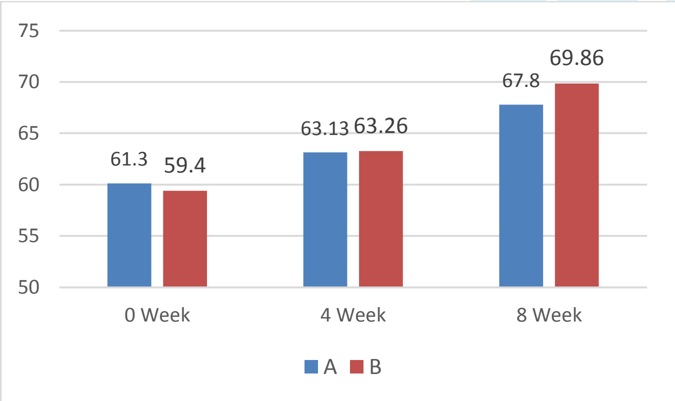
To Analysis the difference within NPRS in Group B

Duration Group A	Mean ±SD	F-value	P-Value	Result
0 week	1.20 ± 1.01	3.818	0.030	Significant
4th week	0.800 ± 0.774			
8th week	0.400 ± 0.507			

NPRS scores reduced from 1.20 ± 1.01 at baseline to 0.800 ± 0.774 at 4 weeks and 0.400 ± 0.507 at 8 weeks. One-way ANOVA revealed a statistically significant reduction in pain over time ($p < 0.05$), indicating effective pain relief and supporting the alternative hypothesis (H1).

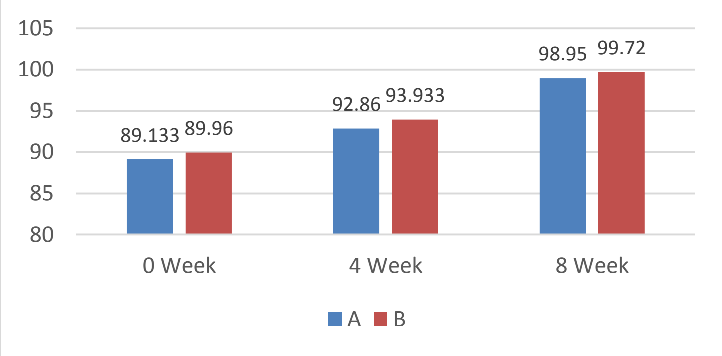
3.3 Groups Comparison

To compare the effect of CMET, SBET L, SBET R and NPRS SCALE, between Groups A and B, Independent t test was used.



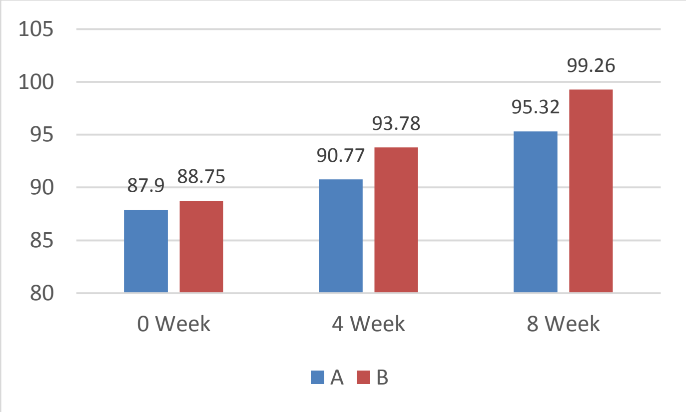
Graph 1 The mean difference between CMET in Group A and Group B

An independent ***t***-test was used to compare CMET scores between Group A (61.3 ± 9.76, 63.13 ± 9.44, 67.80 ± 8.06) and Group B (59.40 ± 5.70, 63.26 ± 6.29, 69.86 ± 8.33) at 0, 4, and 8 weeks. The ***p***-value was less than 0.05, indicating a statistically significant difference in core endurance improvements between the groups over time, favoring Group B.



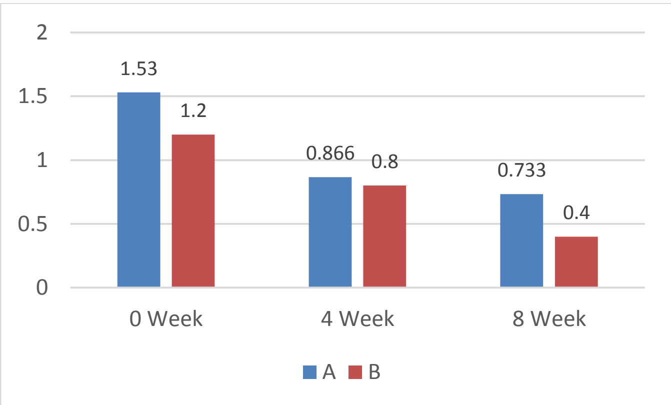
Graph 2 To Analysis the difference between SBET L in Group A and Group B

An independent *t*-test compared SEBT-L scores between Group A (89.13 ± 2.89, 92.86 ± 2.95, 98.95 ± 3.10) and Group B (89.96 ± 3.43, 93.93 ± 3.32, 99.72 ± 3.41) at 0, 4, and 8 weeks. The *p*-value was less than 0.05, indicating a statistically significant difference in dynamic balance between the groups over time, favoring Group B.



Graph 3 The mean difference between SEBT R in Group A and Group B

SEBT R scores in Group A improved from 87.90 ± 3.40 (baseline) to 90.77 ± 3.59 (4 weeks) and 95.32 ± 3.60 (8 weeks), while Group B improved from 88.75 ± 3.54 to 93.78 ± 4.18 and 99.26 ± 4.20 respectively. Independent *t*-test showed a statistically significant difference between the groups at all time points ($p < 0.05$), indicating superior improvement in Group B and supporting the alternative hypothesis (H1).



Graph 4 The mean difference between NPRS Scale in Group A and Group B

NPRS scores in Group A decreased from 1.53 ± 1.06 (baseline) to 0.866 ± 0.639 (4 weeks) and 0.733 ± 0.703 (8 weeks), while Group B showed a reduction from 1.20 ± 1.01 to 0.800 ± 0.774 and 0.400 ± 0.507, respectively. Independent t-test revealed a statistically significant difference between groups across all time points ($p < 0.05$), indicating greater pain reduction in Group B. This supports the alternative hypothesis (H1) and rejects the null hypothesis (H0).

4. Discussion

This study investigated the effects of Core Stabilization Exercises (CSE) and Plyometric Training, both combined with Proprioceptive Training, on strength and stability in recreational athletes with non-contact Anterior Cruciate Ligament (ACL) injuries. A total of 30 participants were randomly assigned into two equal groups. Group A received CSE along with proprioceptive training, while Group B underwent plyometric training with proprioceptive input. The intervention was carried out over a period of 8 weeks, with evaluations at baseline, 4th week, and 8th week. The outcome measures included McGill's Core Muscle Endurance Test (CMET) for strength, Star Excursion Balance Test (SEBT) for dynamic balance (left and right limb reach), and Numerical Pain Rating Scale (NPRS) for pain. Data were analyzed using repeated measures ANOVA and between-group comparisons, with trends also supported by estimated marginal means.

The primary objective was to assess the individual effectiveness of CSE and plyometric training in enhancing core strength and postural stability. The secondary objective was to compare the two protocols to determine which intervention yielded superior outcomes. The results demonstrated that both groups experienced statistically significant improvements from baseline to the 8th week across all outcome parameters ($p < 0.05$), confirming the clinical relevance of both approaches in managing functional deficits following ACL injury. However, the comparative analysis revealed that the Group B (Plyometrics + Proprioceptive training) demonstrated greater improvements across all parameters when compared to Group A.

Specifically, in Group A, CMET scores increased from 61.3 ± 9.76 to 67.80 ± 8.05. SEBT scores for the left limb improved from 89.13 ± 2.89 to 98.95 ± 3.10, and for the right limb from 87.90 ± 3.40 to 95.32 ± 3.60. NPRS scores decreased from 1.53 ± 1.06 to 0.73 ± 0.70, indicating reduced pain. In Group B, CMET scores improved more substantially from 59.40 ± 5.70 to 69.86 ± 8.33. SEBT scores for the left limb rose from 89.96 ± 3.43 to 99.72 ± 3.41, and for the right limb, from 88.75 ± 3.54 to 99.26 ± 4.20. NPRS scores dropped from 1.20 ± 1.01 to 0.40 ± 0.50, demonstrating greater pain relief. The between-group comparison at the 8th week showed significant differences favoring Group B for CMET ($p = 0.04$), SEBT left ($p = 0.03$), SEBT right ($p = 0.021$), and NPRS ($p = 0.004$). These findings suggest that plyometric training combined with proprioceptive inputs is more effective than core stabilization in improving strength, balance, and reducing pain in athletes with ACL injuries.

The enhanced outcomes observed in Group B may be attributed to the high-intensity, multi-planar, and dynamic nature of plyometric exercises, which demand rapid neuromuscular activation and coordination. Plyometric movements such as jumps, hops, and bounds challenge the musculoskeletal and sensorimotor systems simultaneously, leading to improved joint alignment, power output, and reactive balance. When paired with proprioceptive exercises, these gains are likely magnified due to improved joint position sense, enhanced feedback mechanisms, and stronger motor responses. The significant gains in SEBT scores in Group B suggest a greater enhancement in functional dynamic stability—an essential requirement for safe return to sport after ACL injury.

Moreover, the sharper decrease in NPRS scores in the plyometric group indicates not only functional recovery but also a positive influence on pain perception. This may be due to the desensitization of pain pathways through movement repetition, improved neuromuscular control minimizing joint stress, and increased confidence in limb use. Pain reduction plays a crucial role in psychological readiness, which is a key component of successful rehabilitation. The integration of plyometric and proprioceptive training may thus offer a dual benefit: restoring biomechanical function and reducing pain-related fear avoidance behavior. These elements combined could explain the superior performance and clinical relevance of the plyometric approach observed in this study.

These results align with existing literature. Studies by Lephart et al. (2005) and Mandelbaum et al. (2005) support the role of plyometric training in improving neuromuscular control, strength, and proprioceptive feedback in ACL injury rehabilitation. Similarly, Myer et al. (2006) demonstrated that plyometrics enhances the dynamic stabilization of joints by improving feed-forward mechanisms and reactive muscular control. Although core stabilization is known to improve trunk control and reduce compensatory movements, plyometric training may offer additional benefits through explosive, sport-specific movements that mimic real-world athletic demands.

This study acknowledged its limitations like focusing only on short-term outcomes over an 8-week period; therefore, the long-term sustainability of improvements in strength, balance, and pain reduction remains uncertain.The research did not account for variables such as gender, sport discipline, or prior injury history, which may have influenced individual recovery trajectories. There was no follow-up phase to monitor delayed outcomes such as return-to-sport readiness or reinjury rates. Blinding of outcome assessors was not implemented, which may have introduced potential measurement bias during data collection.

Future studies should consider long-term follow-up assessments to evaluate the retention of strength, balance, and pain relief beyond the 8-week intervention period. Research should explore the effects of these training protocols on return-to-sport readiness and prevention of reinjury, which are critical for athletic populations. Including objective performance-based tests (e.g., hop tests, agility drills) could enhance the evaluation of functional recovery and athletic capacity. Studies may investigate the combined effect of CSE and plyometric training, to determine if an integrated protocol yields synergistic benefits. Future research should assess the psychological aspects of rehabilitation, such as confidence, fear of movement, and motivation, to provide a more holistic understanding of recovery outcomes.

Nonetheless, graphical trends from estimated marginal means further reinforced these findings, displaying sharper improvement trajectories in Group B across all outcome domains. Clinically, this suggests that plyometric interventions, especially when integrated with proprioceptive input, could serve as a more comprehensive and functional approach for rehabilitation in active individuals recovering from ACL injuries.

5. Conclusion

Both Core Stabilization Exercises (CSE) and Plyometric Training, when combined with Proprioceptive Training, proved effective in improving core strength, dynamic balance, and pain in individuals with non-contact ACL injuries over an 8-week period. However, the plyometric-based protocol demonstrated superior outcomes across all key measures, likely due to its sport-specific, neuromuscular demands. The integration of proprioceptive training across both groups reinforced its essential role in restoring joint awareness and postural control. These findings support the inclusion of dynamic, task-oriented exercises—particularly plyometrics—in ACL rehabilitation to enhance functional recovery and readiness for return to sport. Future studies should explore long-term efficacy and the potential benefits of combining both modalities for optimized outcomes.

References

1. Duthon VB, Barea C, Abrassart S, Fasel JH, Fritschy D, Ménétrey J. Anatomy of the anterior cruciate ligament. Knee surgery, sports traumatology, arthroscopy. 2006 Mar;14(3):204-13.
2. Jeong J, Choi DH, Shin CS. Core strength training can alter neuromuscular and biomechanical risk factors for anterior cruciate ligament injury. The American journal of sports medicine. 2021 Jan;49(1):183-92.
3. Flom, Cynthia K. Plyometrics. Physical Therapy Scholarly Projects.1993;145.
4. Ma J, Zhang D, Zhao T, Liu X, Wang J, Zheng H, Jin S. The effects of proprioceptive training on anterior cruciate ligament reconstruction rehabilitation: A systematic review and meta-analysis. Clinical Rehabilitation. 2021 Apr;35(4):506-21.
5. Saki F, Shafiee H, Tahayori B, Ramezani F. The effects of core stabilization exercises on the neuromuscular function of athletes with ACL reconstruction. Scientific reports. 2023 Feb 7;13(1):2202.
6. Huxel Bliven KC, Anderson BE. Core stability training for injury prevention. Sports health. 2013 Nov;5(6):514-22.
7. Buckthorpe M, Della Villa F. Recommendations for plyometric training after ACL reconstruction–A clinical commentary. International journal of sports physical therapy. 2021 Jun 1;16(3):879.
8. Khatoon M, Thiyagarajan S. Comparative study to find out the effectiveness of core strengthening training (pilates) versus plyometric training to promote dynamic balance and agility in elite indian badminton players. Indian Journal of Physiotherapy & Occupational Therapy Print-(ISSN 0973-5666) and Electronic–(ISSN 0973-5674). 2021;15(1):85-92.
9. Lubowitz JH, Hwang M, Piefer J, Pflugner R. Anterior cruciate ligament femoral footprint anatomy: systematic review of the 21st century literature. Arthroscopy: the journal of arthroscopic & related surgery: official publication of the Arthroscopy Association of North America and the International Arthroscopy Association. 2014 May;30(5):539-41.
10. Sonnery-Cottet B, Colombet P. Partial tears of the anterior cruciate ligament. Orthopaedics & Traumatology: Surgery & Research. 2016 Feb 1;102(1):S59-67.
11. Guenther D, Herbst E, Musahl V. Anatomy and Biomechanics of the Anterior Cruciate Ligament. InOrthopaedic Biomechanics in Sports Medicine 2021 Oct 19 (pp. 287-295). Cham: Springer International Publishing.
12. Della Villa F, Buckthorpe M, Grassi A, Nabiuzzi A, Tosarelli F, Zaffagnini S, Della Villa S. Systematic video analysis of ACL injuries in professional male football (soccer): injury mechanisms, situational patterns and biomechanics study on 134 consecutive cases. British journal of sports medicine. 2020 Dec 1;54(23):1423-32.
13. Shimokochi Y, Shultz SJ. Mechanisms of noncontact anterior cruciate ligament injury. Journal of athletic training. 2008 Jul 1;43(4):396-408.
14. Waldén M, Krosshaug T, Bjørneboe J, Andersen TE, Faul O, Hägglund M. Three distinct mechanisms predominate in non-contact anterior cruciate ligament

injuries in male professional football players: a systematic video analysis of 39 cases. British journal of sports medicine. 2015 Nov 1;49(22):1452-60.

15. Lin CF, Liu H, Gros MT, Weinhold P, Garrett WE, Yu B. Biomechanical risk factors of non-contact ACL injuries: A stochastic biomechanical modeling study. Journal of Sport and Health Science. 2012 May 1;1(1):36-42.
16. Koga H, Nakamae A, Shima Y, Iwasa J, Myklebust G, Engebretsen L, Bahr R, Krosshaug T. Mechanisms for noncontact anterior cruciate ligament injuries: knee joint kinematics in 10 injury situations from female team handball and basketball. The American journal of sports medicine. 2010 Nov;38(11):2218-25.
17. Renstrom P, Ljungqvist A, Arendt E, Beynnon B, Fukubayashi T, Garrett W, Georgoulis T, Hewett TE, Johnson R, Krosshaug T, Mandelbaum B. Non-contact ACL injuries in female athletes: an International Olympic Committee current concepts statement. British journal of sports medicine. 2008 Jun 1;42(6):394-412.
18. Griffin LY, Agel J, Albohm MJ, Arendt EA, Dick RW, Garrett WE, Garrick JG, Hewett TE, Huston L, Ireland ML, Johnson RJ. Noncontact anterior cruciate ligament injuries: risk factors and prevention strategies. JAAOS-Journal of the American Academy of Orthopaedic Surgeons. 2000 May 1;8(3):141-50.
19. Brophy RH, Wojtys EM, Mack CD, Hawaldar K, Herzog MM, Owens BD. Factors associated with the mechanism of ACL tears in the national football league: a video-based analysis. Orthopaedic journal of sports medicine. 2021 Nov 8;9(11):23259671211053301.
20. Wetters N, Weber AE, Wuerz TH, Schub DL, Mandelbaum BR. Mechanism of injury and risk factors for anterior cruciate ligament injury. Operative Techniques in Sports Medicine. 2016 Mar 1;24(1):2-6.
21. Parsons JL, Coen SE, Bekker S. Anterior cruciate ligament injury: towards a gendered environmental approach. British journal of sports medicine. 2021 Sep 1;55(17):984-90.
22. Geng B, Wang J, Ma JL, Zhang B, Jiang J, Tan XY, Xia YY. Narrow intercondylar notch and anterior cruciate ligament injury in female nonathletes with knee osteoarthritis aged 41–65 years in plateau region. Chinese medical journal. 2016 Nov 5;129(21):2540-5.
23. McLean SG, Huang X, Van Den Bogert AJ. Association between lower extremity posture at contact and peak knee valgus moment during sidestepping: implications for ACL injury. Clinical biomechanics. 2005 Oct 1;20(8):863-70.
24. Mountcastle SB, Posner M, Kragh JF, Taylor Jr DC. Gender differences in anterior cruciate ligament injury vary with activity: epidemiology of anterior cruciate ligament injuries in a young, athletic population. The American journal of sports medicine. 2007 Oct;35(10):1635-42.
25. Price MJ, Tuca M, Cordasco FA, Green DW. Nonmodifiable risk factors for anterior cruciate ligament injury. Current opinion in pediatrics. 2017 Feb 1;29(1):55-64.
26. Hewett TE, Myer GD, Ford KR, Paterno MV, Quatman CE. Mechanisms, prediction, and prevention of ACL injuries: Cut risk with three sharpened and validated tools. Journal of Orthopaedic Research. 2016 Nov;34(11):1843-55.
27. Thomson A, Whiteley R, Bleakley C. Higher shoe-surface interaction is associated with doubling of lower extremity injury risk in football codes: a systematic review and meta-analysis. British Journal of Sports Medicine. 2015 Oct 1;49(19):1245-52.
28. Haim A, Pritsch T, Yosepov L, Arbel R. Anterior cruciate ligament injuries. Harefuah. 2006 Mar 1;145(3):208-14.
29. Olsen OE, Myklebust G, Engebretsen L, Bahr R. Injury Mechanisms for Anterior Cruciate Ligament injuries in Team Handball: A Systematic Video Analysis. Journal of Orthopaedic & Sports Physical Therapy. 2005 Feb;35(2):119.
30. Lambson RB, Barnhill BS, Higgins RW. Football cleat design and its effect on anterior cruciate ligament injuries: a three-year prospective study. The American journal of sports medicine. 1996 Mar;24(2):155-9.
31. Kocher MS, Sterett WI, Zurakowski D, Steadman JR. Effect of Functional Bracing on Subsequent Knee Injury in ACL-Deficient Professional Skiers. The journal of knee surgery. 2003 Apr;16:87-92.
32. McDevitt ER, Taylor DC, Miller MD, Gerber JP, Ziemke G, Hinkin D, Uhorchak JM, Arciero RA, St. Pierre P. Functional bracing after anterior cruciate ligament reconstruction: a prospective, randomized, multicenter study. The American journal of sports medicine. 2004 Dec;32(8):1887-92.
33. Orchard J, Seward H, McGivern J, Hood S. Intrinsic and extrinsic risk factors for anterior cruciate ligament injury in Australian footballers. The American journal of sports medicine. 2001 Mar;29(2):196-200.
34. Musahl V, Nazzal EM, Lucidi GA, Serrano R, Hughes JD, Margheritini F, Zaffagnini S, Fu FH, Karlsson J. Current trends in the anterior cruciate ligament part 1: biology and biomechanics. Knee surgery, sports traumatology, arthroscopy. 2022 Jan;30(1):20-33.
35. Renstrom P, Ljungqvist A, Arendt E, Beynnon B, Fukubayashi T, Garrett W, Georgoulis T, Hewett TE, Johnson R, Krosshaug T, Mandelbaum B. Non-contact ACL injuries in female athletes: an International Olympic Committee current concepts statement. British journal of sports medicine. 2008 Jun 1;42(6):394-412.
36. Souryal TO, Freeman TR. Intercondylar notch size and anterior cruciate ligament injuries in athletes: a prospective study. The American journal of sports medicine. 1993 Jul;21(4):535-9.
37. Kiapour AM, Murray MM. Basic science of anterior cruciate ligament injury and repair. Bone & joint research. 2014 Feb 1;3(2):20-31.
38. Raines BT, Naclerio E, Sherman SL. Management of anterior cruciate ligament injury: what's in and what's out? Indian journal of orthopaedics. 2017 Oct;51(5):563-75.