Evaluation of Double-Leg Postural Control in ACL-Reconstructed and Healthy Athletes Using a Pressure Platform: A Comparative Study

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ABSTRACT

Background: Double-leg stance postural control is essential for stability in athletic and daily movements. While single-leg balance deficits after anterior cruciate ligament reconstruction (ACLR) have been widely studied, double-leg stance may also reveal subtle neuromuscular impairments that persist despite clinical recovery and return to sport.

Objective: To evaluate and compare double-leg postural control between ACL-reconstructed athletes and healthy individuals using a pressure platform.

Methods: A total of 40 athletes (20 with ACLR, 20 healthy controls) were assessed using the Orthoking SDP610 pressure platform under eyes-open and eyes-closed conditions. Parameters including anterior-posterior (AP) sway, latero-lateral (LL) sway, average speed (AS), and average width (AW) of center of pressure were recorded during double-leg stance trials.

Results: No statistically significant differences were found between the ACLR and healthy control groups across all sway parameters under both visual conditions ($p > 0.05$). This suggests comparable double-leg postural control performance in both cohorts.

Conclusion: Double-leg postural control appears to be restored in athletes following ACL reconstruction who have completed rehabilitation and returned to sport. These findings suggest that bilateral stance assessments alone may not be sufficient to detect lingering neuromuscular deficits, highlighting the need for more challenging functional tasks during return-to-sport evaluations.

Keywords: ACL Reconstruction, Double-Leg Stance, Postural Sway, Pressure Platform, Balance Control

INTRODUCTION

Anterior cruciate ligament (ACL) injuries are common in athletic populations and can significantly impair knee stability, neuromuscular coordination, and proprioceptive control. While ACL reconstruction (ACLR) is performed to restore mechanical stability and allow return to sport, the recovery of sensorimotor integration and postural control often remains incomplete, even after rehabilitation and functional clearance [1, 2].

Postural control is the ability to maintain the body's center of mass over its base of support and is a critical component of athletic performance and injury prevention. Although single-leg stance assessments are widely used to detect subtle neuromuscular deficits post-ACLR, double-leg stance—while seemingly simpler—still provides important insights into the overall neuromuscular stability and balance control of athletes. It allows for the assessment of bilateral limb coordination and central nervous system compensation strategies, especially under altered sensory conditions [3].

Double-leg stance tasks are commonly performed in everyday activities and in sport-specific movements such as landing, squatting, and cutting. Evaluating double-leg postural control, particularly under challenging sensory conditions like eyes closed, can help uncover hidden balance impairments that may otherwise go unnoticed during routine clinical examinations [4].

Pressure platforms have emerged as a reliable tool to assess static and dynamic postural stability. These systems quantify subtle deviations in center of pressure (COP) in both the anterior-posterior (AP) and latero-lateral (LL) directions, as well as sway speed and sway width. Such quantitative analysis provides clinicians and researchers with objective data to evaluate postural stability in both clinical and athletic settings [5].

This study aims to evaluate double-leg postural control in athletes with ACL reconstruction and compare it with healthy age- and activity-matched individuals. By analyzing center of pressure parameters under both eyes-open and eyes-closed conditions, the study seeks to determine whether bilateral stance stability is fully restored following rehabilitation and return to sports.

SUBJECTS AND METHODOLOGY

STUDY DESIGN

The study was observational in nature. Convenient sampling was done. The study was performed in the Sports OPD of DAV Institute of Physiotherapy and Rehabilitation, Jalandhar. The duration of study was one and half years. A total of 40 subjects aged between

18-35 years (male and female) were taken for the study and divided into two groups- group A and group B. Group A was ACLR subjects and Group B was control group. Minimum of 20 subjects were allocated in each group.

PROCEDURE

All the subjects were selected based on the following inclusion and exclusion criteria. A written informed consent was obtained from all the subjects. All participants underwent the postural control assessment barefoot to ensure consistent foot contact with the pressure platform. Prior to data collection, a demonstration of the test procedure was provided, and each participant performed a trial run to ensure familiarity and reduce procedural variability.
Participants were asked to assume a comfortable double-leg stance position on the pressure platform with feet shoulder-width apart and arms resting by their sides. They were instructed to remain as still as possible during each trial while focusing on maintaining balance. Each subject performed two testing conditions:

- **Eyes Open (EO):** Participants focused on a fixed visual target placed at eye level approximately 2 meters away.
- **Eyes Closed (EC):** Participants closed their eyes gently after achieving initial stability to eliminate visual feedback.

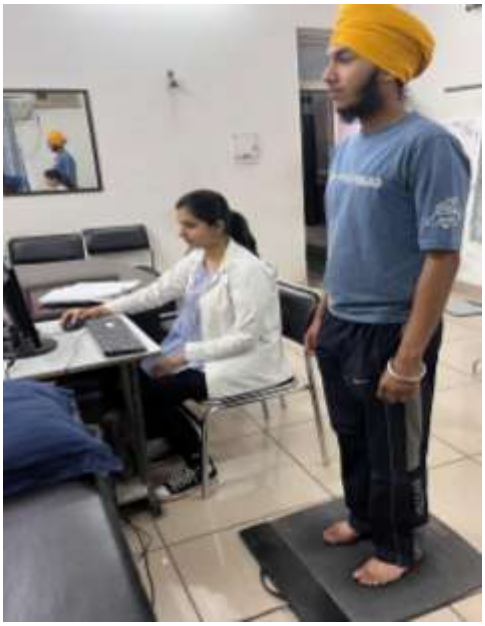

Figure 1: Postural analysis in double-leg standing with eyes open

Figure 2: Postural analysis in double-leg standing with eyes closed.

Each stance was maintained for 30 seconds, during which the pressure platform recorded real-time COP parameters. A one-minute rest was provided between trials to minimize fatigue effects. The parameters recorded included:

- **Anterior-Posterior (AP) Sway:** The extent of forward and backward sway.
- **Latero-Lateral (LL) Sway:** The side-to-side sway magnitude.
- **Average Speed (AS):** The velocity of sway movement in mm/sec.
- **Average Width (AW):** The lateral amplitude of the sway trajectory.

Data from each condition were averaged and analyzed separately for both groups. The primary comparison focused on whether significant differences existed in sway parameters between ACL-reconstructed athletes and healthy controls during double-leg stance.

RESULTS

This study aimed to evaluate and compare the Double-Leg Postural Control in ACL-Reconstructed and Healthy Athletes Using a Pressure Platform. The statistical analysis was performed using SPSS software version 18.0. Level of significance 0.05 was used to determine the statistical significance. Independent sample t-tests were employed to compare postural control parameters between Group A (ACL-reconstructed athletes) and Group B (healthy controls) during double-leg stance. Each sway parameter—including anterior-posterior (AP) sway, latero-lateral (LL) sway, average speed (AS), and average width (AW)—was analyzed separately under eyes-open and eyes-closed conditions. The results showed no statistically significant differences between the two groups across all parameters in both visual conditions, indicating similar postural stability performance following ACL reconstruction. Parameter-specific outcomes are detailed in the following sections.

Double-Leg Stance – Eyes Open
Anterior-Posterior (AS) Sway

Comparison	Group A (Mean ± SD)	Group B (Mean ± SD)	N (each)	Mean Difference	t-value	p-value	Result
Eyes Open – AP AS	3.24 ± 1.846	3.17 ± 2.189	20	0.07	0.109	0.9135	Not Significant

The comparison of the eye-opening score (AP AS) between Group A and Group B shows that the mean score for Group A is 3.24, while for Group B, it is 3.17. The standard deviations for Group A and Group B are 1.846 and 2.189, respectively, indicating the spread of scores around the mean. The mean difference between the two groups is 0.07.
The unpaired t-test value is 0.109, which is much less than the table value of 2.02 at a 0.05 significance level. The p-value is 0.9135, which is greater than 0.05, suggesting that the difference in eye-opening scores between Group A and Group B is not statistically significant. Therefore, we can conclude that there is no significant difference in eye-opening scores between the two groups.

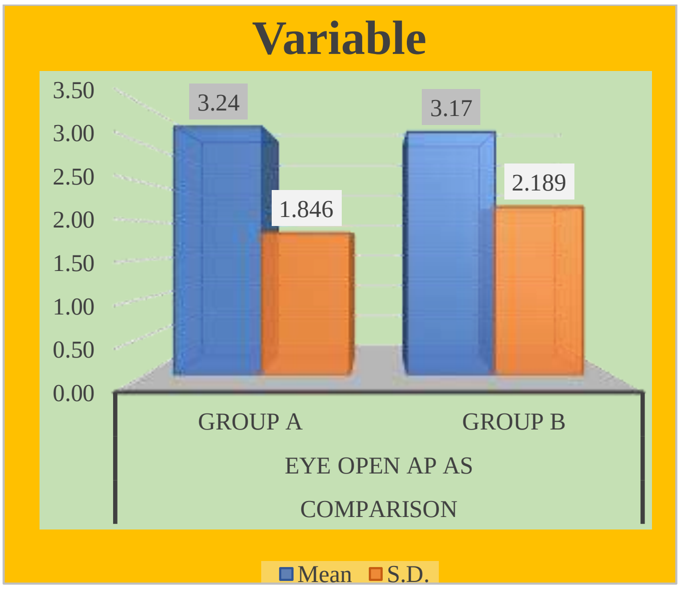

Figure no. 3: Intergroup analysis- Double leg stance with eyes open, anterior-posterior (average speed)
Anterior-Posterior (AW) Sway

Anterior-Posterior (AW) Sway

Comparison	Group A (Mean ± SD)	Group B (Mean ± SD)	N (each)	Mean Difference	t-value	p-value	Result
Eyes Open – AP AW	24.15 ± 15.10	19.91 ± 15.36	20	4.24	0.880	0.3841	Not Significant

The comparison of the eye-opening score (AP AW) between Group A and Group B shows that the mean score for Group A is 24.15, while for Group B, it is 19.91. The standard deviations for Group A and Group B are 15.097 and 15.359, respectively, reflecting the variability in the scores. The mean difference between the two groups is 4.24. The unpaired t-test value is 0.880, which is less than the table value of 2.02 at a 0.05 significance level. The p-value is 0.3841, which is greater than 0.05, indicating that the difference in eye-opening scores between Group A and Group B is not statistically significant. Therefore, we conclude that there is no significant difference in eye-opening scores between the two groups.

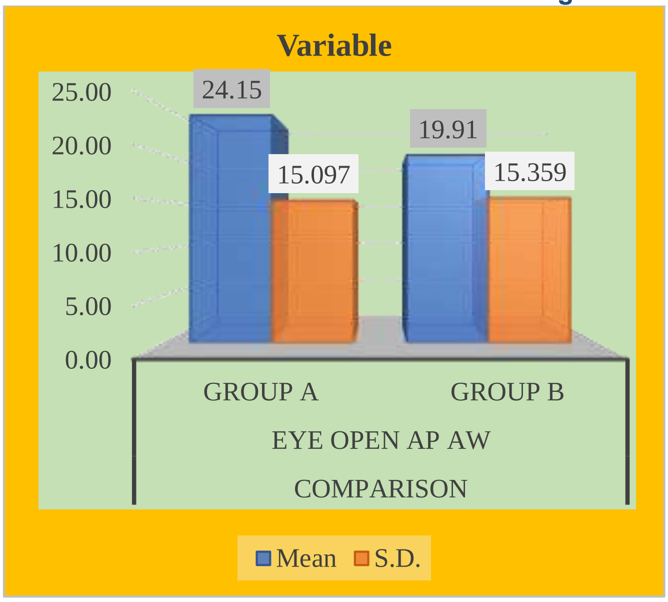

Figure no. 4: Intergroup analysis- Double leg stance with eyes open, anterior-posterior (average width)

Latero-lateral (AS) sway

Comparison	Group A (Mean ± SD)	Group B (Mean ± SD)	N (each)	Mean Difference	t-value	p-value	Result
Eyes Open – LL AS	3.61 ± 2.38	3.48 ± 2.25	20	0.13	0.185	0.8545	Not Significant

The comparison of the eye-opening score (LL AS) between Group A and Group B shows that the mean score for Group A is 3.61, while for Group B, it is 3.48. The standard deviations for Group A and Group B are 2.376 and 2.248, respectively, indicating a similar level of variability in both groups. The mean difference between the two groups is 0.13. The unpaired t-test value is 0.185, which is much smaller than the table value of 2.02 at a 0.05 significance level. The p-value is 0.8545, which is greater than 0.05, indicating that the difference in eye-opening scores between Group A and Group B is not statistically significant. Therefore, we conclude that there is no significant difference in eye-opening scores between the two groups.

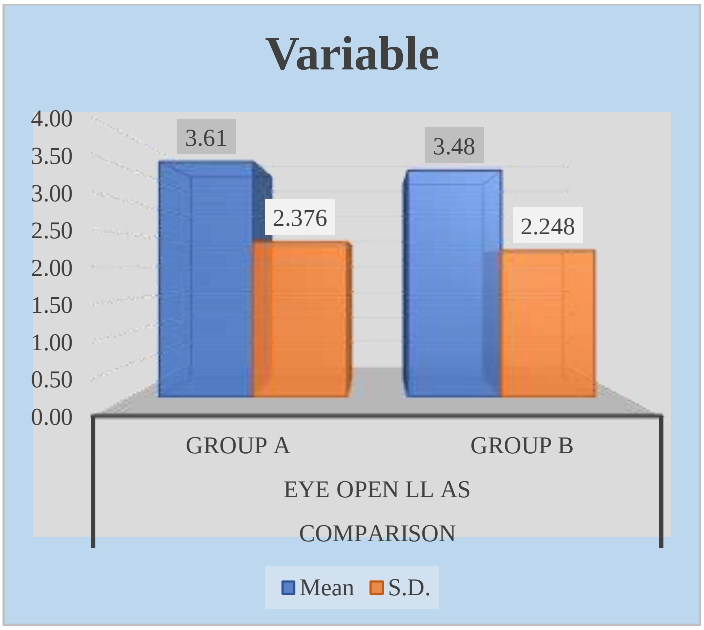

Figure no. 5: Intergroup analysis- Double leg stance with eyes open, latero-lateral (average speed (mm/s))

Latero-lateral (AW) sway

Comparison	Group A (Mean ± SD)	Group B (Mean ± SD)	N (each)	Mean Difference	t-value	p-value	Result
Eyes Open – LL AW	20.83 ± 22.07	16.98 ± 17.09	20	3.85	0.617	0.5410	Not Significant

The comparison of the eye-opening score (L AW) between Group A and Group B shows that the mean score for Group A is 20.83, while for Group B, it is 16.98. The standard deviations for Group A and Group B are 22.068 and 17.086, respectively, indicating considerable variability in both groups. The mean difference between the two groups is 3.85. The unpaired t-test value is 0.617, which is much smaller than the table value of 2.02 at a 0.05 significance level. The p-value is 0.5410, which is greater than 0.05, indicating that the difference in eye-opening scores between Group A and Group B is not statistically significant. Therefore, we conclude that there is no significant difference in eye-opening scores between the two groups.

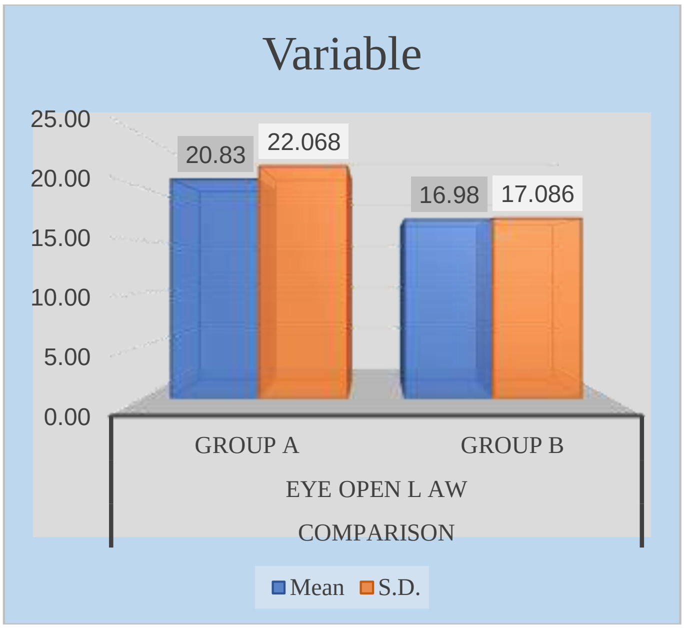

Figure no. 6: Intergroup analysis- Double leg stance with eyes open, latero-lateral (average width (mm))

Double-Leg Stance – Eyes Closed

Anterior-Posterior (AS) Sway

Comparison	Group A (Mean ± SD)	Group B (Mean ± SD)	N (each)	Mean Difference	t-value	p-value	Result
Eyes Closed – AP AS	2.72 ± 1.37	3.04 ± 1.96	20	–0.32	0.590	0.5586	Not Significant

The comparison of the eye-closing score (AP AS) between Group A and Group B shows that the mean score for Group A is 2.72, while for Group B, it is 3.04. The standard deviations for Group A and Group B are 1.367 and 1.957, respectively, indicating that Group B has more variability in eye-closing scores. The mean difference between the two groups is -0.32. The unpaired t-test value is 0.590, which is much smaller than the table value of 2.02 at a 0.05 significance level. The p-value is 0.5586, which is greater than 0.05, indicating that the difference in eye-closing scores between Group A and Group B is not statistically significant. Therefore, we conclude that there is no significant difference in eye-closing scores between the two groups.

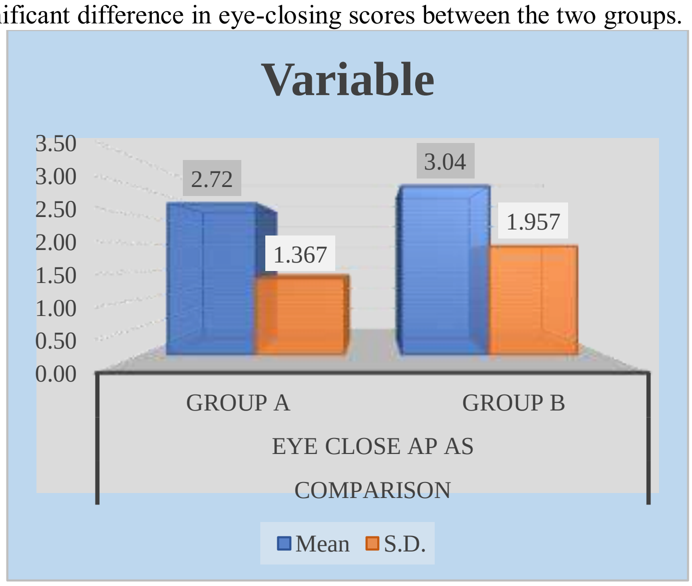

Figure No. 7: Intergroup analysis- Double leg stance with eyes closed, anterior-posterior (average speed (mm/s))

Anterior-Posterior (AW) sway

Comparison	Group A (Mean ± SD)	Group B (Mean ± SD)	N (each)	Mean Difference	t-value	p-value	Result
Eyes Closed – AP AW	16.94 ± 12.33	24.26 ± 22.22	20	–7.32	1.288	0.2055	Not Significant

The comparison of the eye-closing score (AP AW) between Group A and Group B shows that the mean score for Group A is 16.94, while for Group B, it is 24.26. The standard deviations for Group A and Group B are 12.333 and 22.224, respectively, indicating that Group B has higher variability in eye-closing scores. The mean difference between the two groups is -7.32. The unpaired t-test value is 1.288, which is smaller than the table value of 2.02 at a 0.05 significance level. The p-value is 0.2055, which is greater than 0.05, indicating that the difference in eye-closing scores between Group A and Group B is not statistically significant. Therefore, we conclude that there is no significant difference in eye-closing scores between the two groups.

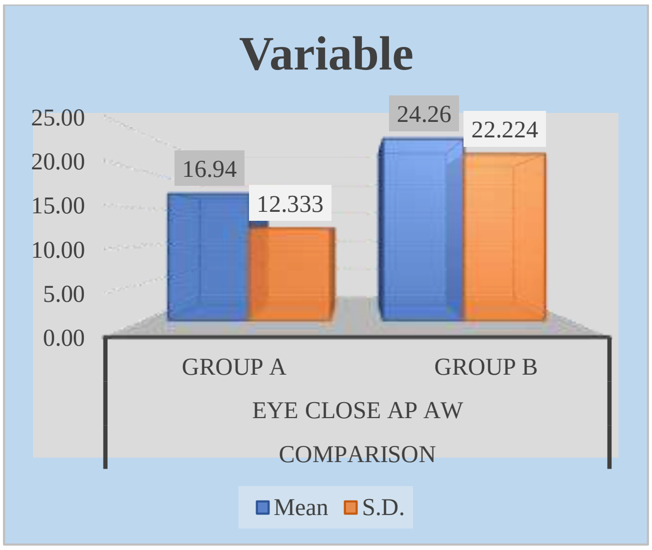

Figure No. 8: Intergroup analysis- Double leg stance with eyes closed, anterior-posterior (average width (mm))

Latero-lateral (AS) Sway

Comparison	Group A (Mean ± SD)	Group B (Mean ± SD)	N (each)	Mean Difference	t-value	p-value	Result
Eyes Closed – LL AS	2.83 ± 1.39	2.97 ± 1.45	20	–0.14	0.311	0.7574	Not Significant

The comparison of the eye-closing score (LL AS) between Group A and Group B shows that the mean score for Group A is 2.83, while for Group B, it is 2.97. The standard deviations for Group A and Group B are 1.392 and 1.453, respectively, indicating similar variability in both groups. The mean difference between the two groups is -0.14. The unpaired t-test value is 0.311, which is much smaller than the table value of 2.02 at a 0.05 significance level. The p-value is 0.7574, which is greater than 0.05, indicating that the difference in eye-closing scores between Group A and Group B is not statistically significant. Therefore, we conclude that there is no significant difference in eye-closing scores between the two groups.

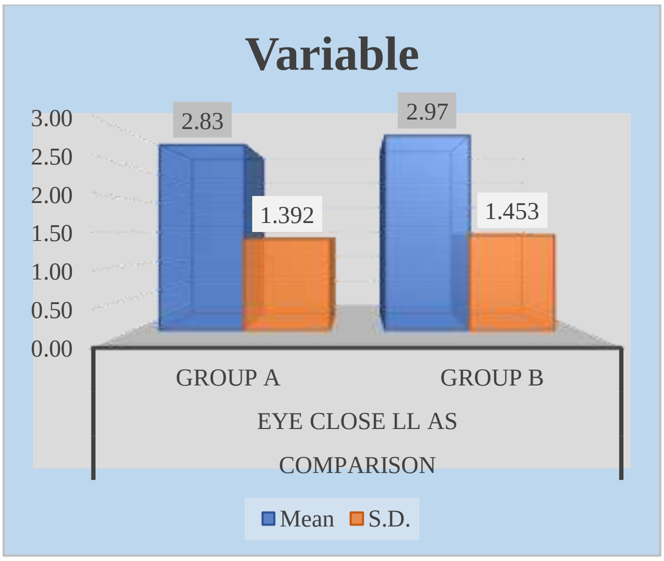

Figure No. 9: Intergroup analysis- Double leg stance with eyes closed, latero-lateral (average speed (mm/s))

Latero-lateral (AW) Sway

Comparison	Group A (Mean ± SD)	Group B (Mean ± SD)	N (each)	Mean Difference	t-value	p-value	Result
Eyes Closed – LL AW	15.20 ± 13.67	14.34 ± 11.61	20	0.86	0.214	0.8313	Not Significant

The comparison of the eye-closing score (LL AW) between Group A and Group B shows that the mean score for Group A is 15.20, while for Group B, it is 14.34. The standard deviations for Group A and Group B are 13.669 and 11.605, respectively, indicating variability in both groups. The mean difference between the two groups is 0.86. The unpaired t-test value is 0.214, which is much smaller than the table value of 2.02 at a 0.05 significance level. The p-value is 0.8313, which is greater than 0.05, indicating that the difference in eye-closing scores between Group A and Group B is not statistically significant. Therefore, we conclude that there is no significant difference in eye-closing scores between the two groups.

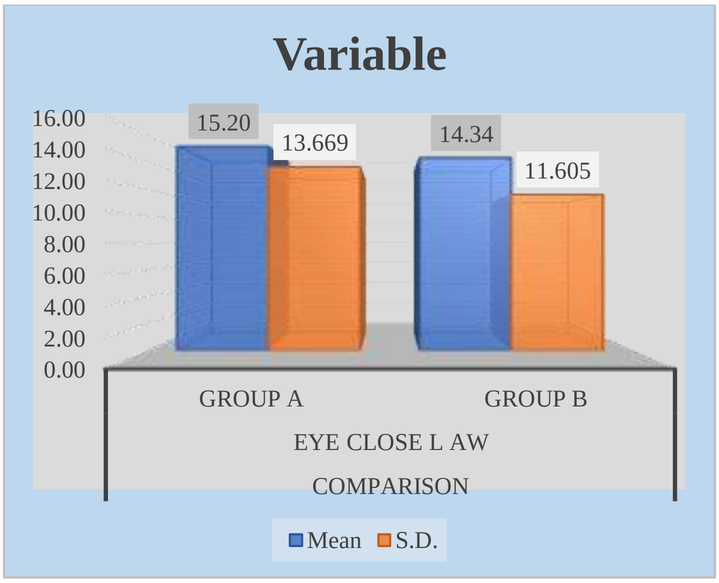

Figure No. 10: Intergroup analysis- Double leg stance with eyes closed, latero-lateral (average width (mm))

DISCUSSION

The present research indicated that there were no statistically significant differences in postural control between athletes who had ACL reconstruction (Group A) and healthy individuals (Group B). This encompassed anterior-posterior (AP) sway, latero-lateral (LL) sway, average speed (AS), and average width (AW) in both eyes-open and eyes-closed scenarios for double-leg stances.". Specifically, for the double-leg stance with eyes open, analyses showed that "there was no statistically significant difference between the groups" for all measured parameters (Intergroup Analysis for Double-Leg Stance with Eyes Open). Similarly, for the double-leg stance with eyes closed, results consistently indicated "no statistically significant difference" between the groups (Intergroup Analysis for Double-Leg Stance with Eyes Closed).

This finding aligns with existing literature, as "A similar study conducted by Ferdowsi et al (2021) reported no significant difference in response to constant loading between the healthy and ACLR group" [6].The mechanism for maintaining this stability is described: "Postural stability in double-leg standing is achieved when a healthy sensory-motor system uses the activation freezing method, muscular contraction, and shifting strategy in response to a consistent load" [7]. However, for static assessments, Kouvelioti V, Kellis E, Kofotolis N, Amiridis I showed that "30-second tests in single-leg and double-leg are reliable tools for reliability to assess static balance," with "the ICC was higher for double-leg tests than for single-leg ones"[8]

In summary, this study demonstrates that "there was no significant difference between the single-leg and double-leg postural control with eyes open and closed amongst patients with ACLR and healthy individuals" particularly emphasizing the comparable double-leg postural stability.

LIMITATIONS AND FUTURE SCOPE

This study had a few limitations that should be acknowledged. Firstly, the sample size was relatively small, which may limit the generalizability of the findings. Secondly, the study focused exclusively on athletes who had already completed their rehabilitation and returned to sport, thereby excluding individuals who were still in the recovery phase or those who are not athletes. As a result, the findings may not be applicable to the broader population of individuals with ACL injuries. For future research, incorporating an intervention phase—such as balance training or proprioceptive exercises—and measuring postural sway both before and after the intervention could provide valuable insights into the effectiveness of specific rehabilitation strategies on postural control outcomes.

CONCLUSION

Based on the findings presented in the document, it can be concluded that "there was no significant difference between the single-leg and double-leg postural control with eyes open and closed amongst patients with ACLR and healthy individuals". This study was primarily "performed to observe and evaluate single-leg and double-leg postural control among subjects with anterior cruciate ligament reconstruction in athletes and healthy individuals using a pressure platform". The results, therefore, indicate that for fundamental static balance tasks involving either single or double-leg stances, and with eyes open or closed, individuals who have undergone ACL reconstruction demonstrate postural control comparable to that of healthy individuals.

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