Title: Balance Training Combined with a Secondary Cognitive Task versus Balance Training in Individuals with Anterior Cruciate Ligament Reconstruction: A Randomized Controlled Trial

Running Title: Dual-Task Balance Training in ACL Reconstruction

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Abstract

Background: Previous studies have suggested that Anterior cruciate ligament (ACL) injury is a common musculoskeletal injury. In ACL deficiency, neuromuscular functions are altered due to factors such as pain, instability, fear, and damaged mechanoreceptors.

Purpose: To compare the effects of balance training plus cognitive tasks with balance training only.

Methods: A group of 26 patients with ACL reconstruction (ACLR) was randomly allocated into two groups: balance training plus cognitive tasks (n = 13) and balance training only (n = 13). All patients received 12 sessions of treatment for 4 weeks. After the end of treatment, the Star Excursion Balance Test (SEBT), Center of pressure (COP) variables used to measure postural performance included sway area (95% confidence ellipse) as well as mean and standard deviation of velocity in anterior–posterior (AP) and medial–lateral (ML) directions, The Knee Injury and Osteoarthritis Outcome Score (KOOS), and Tegner activity scale used to record changes in participants post-treatment.

Results: The balance training plus cognitive tasks group showed significantly more performance in three directions of SEBT test status compared with the balance training group, but there was no significant difference in other outcomes between the two groups.

Conclusion: Balance training, whether combined with cognitive tasks or performed alone, may effectively improve the functional abilities of patients following ACLR surgery.

Keywords: Anterior Cruciate Ligament Reconstruction, Post-surgical, Knee, Cognition, Clinical trials, Balance training, Dual-task

Introduction

Anterior cruciate ligament (ACL) injury is a common musculoskeletal injury. (Arumugam et al., 2021), which is most prevalent in young individuals (Pirayeh et al., 2023, 2025; Sanders TL, n.d.). This injury occurs more often during competition rather than training, with ~70% or more of the injuries representing noncontact mechanisms. (Johnston et al., 2018) such as landing from a jump, sudden deceleration, and/or while cutting (Arumugam et al., 2021). In ACL deficiency, neuromuscular functions are altered due to factors such as pain, instability, fear, and damaged mechanoreceptors. (Nazary-Moghadam et al., 2019). Bilateral sensory deficits may result from post-traumatic inactivity or centrally mediated changes. A growing body of brain activation imaging research has shown that ACL deficiency can cause reorganization of the central nervous system at both spinal and supraspinal levels. (Kapreli et al., 2009). These changes appear to persist following ACLR. (Baumeister et al., 2008), thus potentially resulting in bilateral postural control impairments. ACLR is frequently performed to restore mechanical stability following an ACL injury. However, despite successful rehabilitation, long-term neuroplastic changes (Lepley et al., 2019), cognitive performance deficits (Stone et al., 2018), and movement impairments (Paterno et al., 2007) Often, they persist even after the completion of recovery. Up to 91% of young athletes return to strenuous sports following an ACLR. (Monfort et al., 2022), while approximately a third of these athletes will experience a second ACL tear after surgery (Monfort et al., 2022). This persistent high risk of injury highlights the need for a more comprehensive understanding of cognitive issues and neuromuscular alterations following ACLR.

The results of previous studies indicate that incorporating cognitive load can reduce postural stability in patients with ACL injury as measured by changes in the center of pressure on force plate instruments. In other words, the interference between motor and cognitive tasks can cause changes in the motor function of individuals (Burcal et al., 2019; Negahban et al., 2009). ACLR results in subsequent neurologic and neuromuscular sequelae, which are likely contributors to these observed performance differences (Baumeister et al., 2011; Stone et al., 2018). For example, during a force reproduction task, individuals with

ACLR exhibited increased frontal lobe activation compared to healthy adults, suggesting these individuals may require more cognitive resources related to working memory and attention to perform the task (Baumeister et al., 2011). Additionally, cortical activation differences in ACLR individuals, specifically, increased activation in the secondary somatosensory area and lingual gyrus (Kapreli et al., 2009).

Balance training shows the ability to moderately enhance dynamic stability measures during initial rehabilitation phases after ACLR. (Akbari et al., 2015). Recent research emphasizes incorporating balance-focused regimens as a fundamental element of post-surgical recovery programs. (Akbari et al., 2015; Karimijashni et al., 2023). Despite achieving satisfactory clinical functional outcomes through structured rehabilitation protocols, patients continue facing elevated risks of secondary injuries. (Buckthorpe et al., 2020). This paradox may stem from compromised movement control under real-world conditions, where environmental stimuli and psychological stressors differ markedly from controlled clinical environments. (Buckthorpe et al., 2020; Du et al., 2025). The cognitive demands and unpredictable nature of daily activities/sports appear to expose residual neuromuscular deficiencies not adequately addressed by conventional clinic-based rehabilitation approaches in environments. (Buckthorpe et al., 2020; Du et al., 2025).

Based on evidence regarding the functional impairments experienced by patients with ACL injuries—particularly during dual-task activities—and the observed benefits of dual-task exercises on balance and cognitive function in various patient populations (Azadian et al., 2016; Burcal et al., 2019; Fritz et al., 2015; Nazary-Moghadam et al., 2019; Negahban et al., 2013) Further research appears necessary to consider the cognitive capacity of individuals to better understand the relationship between musculoskeletal injuries and cognitive processing abilities. (Burcal et al., 2019). The hypothesis posits that dual-task balance exercises, which integrate a cognitive component, will yield greater improvements in postural control, activity levels, and functional ability in patients following ACLR compared to single-task balance exercises.

Materials and Methods

Study design and participants

This study was a parallel-group randomized controlled trial with a before-and-after design. This was approved by the Ethics committee of *** University of Medical Sciences, ***, *** (***). Moreover, the trial was registered at the *** Registry of Clinical Trials (registration number: ***).

Twenty-six individuals who had undergone ACLR were enrolled in this study. All participants provided informed consent before their involvement. To qualify for the study, participants had to meet the following criteria: 1) aged between 16 and 50 years, 2) at least 6 weeks post-ACL reconstructive surgery, 3) minimal knee joint effusion, 4) a range of motion of 0–120 degrees in the affected knee, 5) the ability to walk without assistive devices, and 6) confirmation of eligibility by an orthopedic specialist based on physical examinations and imaging findings. (Cooper et al., 2005; Johnson, 2000; Mostafaee et al., 2017). Participants were excluded from the study if they met any of the following criteria: 1) neurological, cardiac, or respiratory conditions; 2) a history of neuromuscular disorders or prior surgeries on the lower extremities; 3) visual impairments or vestibular disorders; 4) a pain level exceeding 2 on the Visual Analog Scale (VAS); 5) use of medications that reduce alertness or induce drowsiness; or 6) a diagnosis of osteoporosis, knee osteoarthritis, or any fractures in the lower extremities. (Akbari et al., 2015; Negahban et al., 2013).

Randomization

After reviewing the basic information, participants were randomized to two groups: a control group, which performed balance exercises, and an intervention group, which engaged in balance exercises combined with cognitive tasks. Allocation to the control or intervention group was conducted using sealed envelopes through block randomization, consisting of four blocks divided into six modes. Participants were randomly assigned to either group, and this process continued until all participants were allocated. While the assessor and data analyst were blinded to the group assignments, the nature of the exercise-based interventions prevented blinding for both participants and the physiotherapist conducting the training.

Sample size

Based on Asadi's study (Asadi et al., 2015) and the star excursion balance test (SEBT) outcome, the total sample size of the study was calculated to be 26 people with a power of 0.80. A total of 26 subjects undergoing ACLR surgery were referred to the Imam-Reza Hospital of Mashhad University of Medical Sciences by an orthopedic surgeon. The subjects were selected using a non-probability convenience sampling method from January to November 2024.

Interventions

Patients in both groups underwent a 4-week treatment program, consisting of three 60-minute sessions per week, totaling 12 sessions.

First, both groups undergo functional electrical stimulation (FES) for 15 minutes, which was applied to the quadriceps femoris muscle. Following the electrotherapy session, participants engaged in 15 minutes of strengthening exercises focused on the lower extremity muscles, especially the quadriceps femoris. This was complemented by stretching exercises, which included the posterior calf muscles, quadriceps femoris, and hamstrings. If a patient exhibits joint inflammation, ultrasound treatment is applied at a frequency of 1 MHz for 5 to 10 minutes. Additionally, knee joint mobilization were exercises incorporated as part of the standard treatment regimen. (Akbari et al., 2015; Fu et al., 2013; Raju et al., 2018). Specific balance exercises were implemented, which included standing on one leg and both legs as well, as well as standing on a narrow surface under varying support levels in both open and closed visual conditions. Additional activities involved walking forward, backward, and sideways on different surfaces (such as soft underfoot) while navigating obstacles and climbing stairs. In the intervention group, balance exercises accompanied by secondary cognitive tasks are done simultaneously with the patient's movements. (Monjezi et al., 2017). In the initial sessions of the intervention group, the individuals were asked to perform a simple cognitive task during balance exercises (such as naming words that belonged to a category and reciting the days of the week or months in reverse order). In the final sessions, the balance exercises in the intervention group were accompanied by more challenging cognitive tasks (such as recalling the alphabet, remembering numbers, and naming words that start with the same letter).

Cognitive tasks included the following: 1) Recall of items or words: this involves naming four words or four three-digit numbers that have been previously presented to the individual, as well as recalling six words or six three-digit numbers mentioned earlier. Additionally, participants were asked to name a number, such as a mobile phone number. 2) Reversing words or sequences: this task includes reciting the days of the week, the solar months of the year, and the alphabet in reverse order. 3) Naming words in different categories: participants name words from specific categories, such as animals and fruits. The first three tasks structured in three levels of difficulty, ranging from easy to challenging (Monjezi et al., 2017; van Wyk et al., 2014). The cognitive exercises mentioned engage various cognitive domains, including working memory, visual-spatial, and executive function. (Bayot et al., 2018).

Outcome measures

To prevent learning effects and fatigue, outcome measurements were conducted randomly. In the first session, the patient was familiarized with the environment and the tests. The outcomes, which included the following measures, were assessed both before and after the completion of the treatment sessions.

Primary outcome

Dynamic balance test

The Star Excursion Balance Test (SEBT) has been described as a test of dynamic postural control because it challenges an individual's ability to maintain a stable base of support while performing the reach movement. While maintaining a single-leg stance, each participant was asked to maximally reach along the identified line with the contralateral limb and lightly touch the line with the distal part of the foot. All reach trials began with both feet in contact with the ground and with the stance leg appropriately positioned in relation to the center of the SEBT grid. (Asadi et al., 2015; Dobija et al., 2019). Research findings have shown that the SEBT is a reliable test for predicting the risk of lower limb injuries and identifying dynamic balance deficits during movements under various lower limb conditions. This scale demonstrates high repeatability and acceptable responsiveness. (Dobija et al., 2019; Gribble et al., 2012; Mostafaee et al., 2021).

Secondary outcomes

Static balance test

A force platform is a tool that measures body posture and uses fluctuating amplitude to evaluate this information. Participants were asked to stand barefoot with eyes open on their injured leg, with their arms hanging relaxed at their sides, and the hip and knee joints of the non-weight-bearing limb both in 90° flexion. Center of pressure (COP) variables used to measure postural performance included the sway area (95% confidence ellipse) as well as the mean and standard deviation of velocity in anterior–posterior (AP) and medial–lateral (ML) directions. The reliability and responsiveness of these measures have been documented in the literature. (Mostafaee et al., 2017; Salavati et al., 2009). The data recording time for each test was 30 seconds, with a 1-minute break between each test. If a participant was unable to maintain the single-leg stance for 30 s in each condition, the trial was not recorded, and the test could be repeated up to a maximum of three attempts. (Hadian et al., 2008; Kouvelioti et al., 2015). The examiner engaged the patient in two cognitive activities simultaneously while administering the motor test. This approach aimed to reduce the patient's focus on the test itself and to assess the impact of the cognitive tasks on the execution of the motor test. Two cognitive tasks, silent backward counting (BC) and the Stroop Color Word test (SCWT), were employed while patients stood on a force plate.

In the BC task, the examiner selected a three-digit number, and the participants were asked to mentally subtract 7 from that number repeatedly. After 30 seconds of data collection, the participants were asked to verbalize the last number they had in their mind. (Negahban et al., 2013). In the SCWT test, the names of the colors were written in a different color other than their own (for example, the word blue was written red), and the person was asked to say the name of the color instead of the written word. (Scarpina & Tagini, 2017).

Functional disability measure

The Tegner activity scale was used to record the activity level of both groups. The numerical range of this scale ranges from 0 to 10. The higher the score on this scale, the higher the level of activity (Negahban et al., 2011). The Knee Injury and Osteoarthritis Outcome Score (KOOS) was used to evaluate knee function in potentially stressful knee movements over the week before testing. The KOOS includes five subscales with a scoring range of 0–100. Higher scores represent mild knee problems (0 = severe disability, 100 = no disability). The Persian versions of KOOS and Tegner activity scale are reliable and valid outcome measures used for ACLR patients. (Negahban et al., 2011; Salavati et al., 2008). The responsiveness of these two questionnaires has been assessed by researchers. (Mostafaee et al., 2020).

Statistical Analyses

Data were analyzed with Statistical Package for Social Sciences (SPSS) software (Version 26.0), and the P value <0.05 was considered statistically significant. To check the normality of the data distribution, the Kolmogorov-Smirnov test (K-S test). To compare the two groups in terms of quantitative background variables, an independent t-test or its nonparametric equivalent. Comparing the two groups for qualitative background variables used the chi-square test. The ANCOVA test was employed to control for the basic effect of variables. Statistical tests were performed using statistical software and 95% confidence and α=0.05.

Results

Participant characteristics

Among 54 patients who were referred to the clinic, 20 did not meet the inclusion criteria, and 8 were unwilling to participate in the study due to personal reasons. Finally, 26 individuals participated in the study

(Fig. 1). The results of the K-S test showed that all characteristic variables had a normal distribution. There was no statistically significant difference in the demographic information of the participants between the two groups [Table 1]. The results of the independent t-test for age, height, weight, BMI, and the Chi-square test for gender, involved leg, dominant leg, and meniscus status [Table 1] exhibited no significant difference between the two groups before interventions (P>0.05).

Dynamic balance assessment

The paired sample t-test showed that both groups increased all directions of the SEBT test (P<0.05). In the between-group analysis, there was a significant difference in three directions in the ACLR group (posteromedial: ES[1]=0.30, 0.95 CI[2]: lower bond= -14.39, upper bond= -11.90), (posterior: ES=0.69, 0.95 CI: lower bond= -15.39, upper bond= -11.68), and (lateral: ES=0.28, 0.95 CI: lower bond= -13.18, upper bond= -11.35) (P<0.05), however, other directions (anterior: ES= 0.13, 0.95 CI: lower bond= -13.01, upper bond= -10.14) ,(anteromedial: ES=o.oo, 0.95 CI: lower bond= -12.70, upper bond= -10.06),(medial: ES=0.01, 0.95 CI: lower bond= -14.44, upper bond= -11.70),(posterolateral: ES=0.09, 0.95 CI: lower bond= -14.23, upper bond= -12.14),(anterolateral: ES=0.07, 0.95 CI: lower bond= -11.37, upper bond= -9.16) showed no statistically significantly difference (P>0.05) [Table 2].

Static balance assessment

Some parameters of force plate variables in groups did not have a normal distribution. Outlier data in these variables were normalized and corrected using the logarithm base 10 (log 10) method. Within-group analysis showed that both types of interventions had a significant effect in reducing the value of all dependent variables related to static balance. The results of the paired t-test for almost all variables of static balance were significant in both groups(P<0.05). For between-group analysis, after the interventions, the

[1] Partial Eta Squared
[2] Confidence interval

results of the ANCOVA test showed no significant difference in force plate parameters between the two groups(P>0.05) [Table 3].

Functional disability

In both groups after interventions, the scores of the KOOS increased significantly (P<0.05) in all subscales of the questionnaire [Table 4]. In addition, the Tegner score increased significantly after treatments. However, in the between-group analysis, the result showed no significant difference in both of the questionnaire's subscale scores between the two groups (P>0.05).

Discussion

The primary objective of this study was to compare the effectiveness of balance exercises with cognitive tasks versus those balance exercises alone. This was achieved by analyzing data from the SEBT test, force plate parameters, and Tegner and KOOS questionnaires. Our findings showed that there were no significant differences between the two groups across most variables, except for three directions in the SEBT balance-movement test. However, significant improvements were observed in nearly all assessed variables before and after treatment in both groups, except some force plate parameters. The findings of this study highlight the effectiveness of ACLR rehabilitation in improving postural stability. Specifically, balance exercises were shown to significantly enhance both dynamic and static stability, contributing to improved overall function, activity levels, and balance in patients. These results suggest that incorporating balance exercises into rehabilitation programs for individuals recovering from ACLR can be highly beneficial for restoring postural stability. Moreover, the study's outcomes are consistent with similar research findings, further validating its conclusions. (Akbari et al., 2015; Asadi et al., 2015; Mazidluie et al., 2024).

In our study, the outcomes related to the SEBT test improved after treatment in each group, and the test score increased significantly. Based on some studies, performing balance exercises, proprioception exercises, and neuromuscular exercises has a strong association with the SEBT outcome(Asadi et al., 2015).

Standing on a balance board strengthens and activates movement patterns in multiple directions. Additionally, it enhances proprioception by correcting and refining movement feedback (Curtis et al., 2017). No study was found that examined balance exercises combined with cognitive tasks in relation to the SEBT variable. However, given that this test evaluates dynamic balance and considering that balance-cognitive exercises improve balance maintenance, the SEBT might be able to show the differences in the effects of cognitive exercises on balance exercises.

The results of our study align with those of Hallaj Mazidluie et al (2024), who conducted a similar investigation comparing balance exercises with cognitive tasks to balance exercises performed separately. This study observed improvements in postural stability and function, as measured by KOOS and foot pressure tool (FDM pressure platform) variables, before and after treatment. However, they could not found significant differences between the groups, suggesting that balance exercises with cognitive tasks did not demonstrate superiority over separate balance exercises. (Mazidluie et al., 2024). Several factors may explain the lack of significant differences between the two groups in our study; firstly, both groups received the same therapeutic program, including electrotherapy, strengthening and stretching exercises, joint mobilization, and balance training. The only difference between the groups was the inclusion of secondary cognitive exercises. The intervention group performed these cognitive tasks simultaneously with balance exercises as dual-task training, whereas balance training alone—supported by existing literature—is effective in patients' rehabilitation. Secondly, cognitive task difficulty: according to the cognitive task difficulty theory, more challenging cognitive tasks lead to greater improvements in motor performance under dual-task conditions (Huxhold et al., 2006). The cognitive tasks in our dual-task group may not have been sufficiently challenging for the neural pathways of our young participants, thus not significantly affecting their balance. Perhaps these cognitive tasks failed to demonstrate a broader significant effect due to a ceiling effect. It is plausible that the primary physical exercises themselves were sufficiently effective, leaving limited room for additional measurable improvement from the cognitive component. Thirdly, participant demographics: previous studies demonstrating the superior effectiveness of cognitive dual-task exercises over single-task exercises for improving balance and walking have primarily focused on elderly groups and neurological patients (Elhinidi et al., 2016). In contrast, our study involved young individuals with good cognitive abilities, which may have limited the potential for improvement from dual-task training.

Based on the findings of this study, both cognitive dual-task and single-task balance exercises resulted in increased KOOS scores. Higher scores on the questionnaire indicate better functional status and less disability. (Roos & Lohmander, 2003; Salavati et al., 2008). However, there was no statistically significant difference between the two groups after the interventions, which showed cognitive dual-task balance exercises at the functional level measured with the KOOS questionnaire are not preferable to single-task balance exercises in ACL reconstructed individuals. Studies have shown that balance exercises effectively improve both static and dynamic stability. (Akbari et al., 2015; Mazidluie et al., 2024). Therefore, both groups received balance exercises, which led to an improvement in stability for these individuals, and the questionnaire scores showed sufficient improvement for both groups.

Conclusion

The findings of this study indicated that adding cognitive tasks to balance training did not yield a greater overall improvement in the dynamic balance for patients with ACLR, compared to balance training alone. Notably, however, significant improvements were observed in three specific directions of the SEBT within the dual-task group. No other outcomes showed significant differences between the two groups.

Limitations

The participants in this study were exclusively male, and the results cannot be generalized to the population of females with ACLR.

Conflict of interest

The authors declare that they have no conflict of interest.

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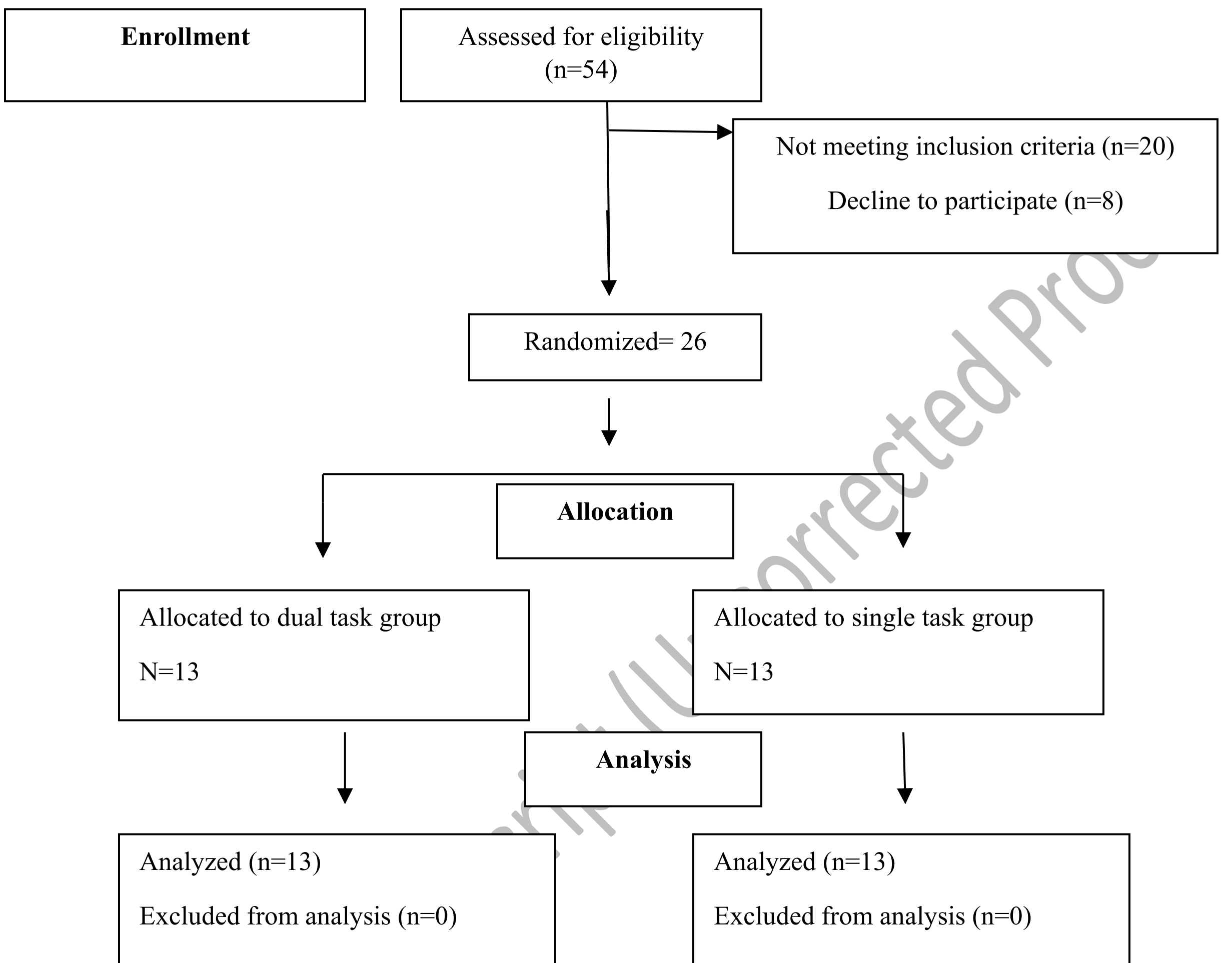
Figure 1: Flowchart diagram of participants through the study



The designated location for Figure 1 is in the Methodology section, immediately after the discussion of the sample size.

Table 1. Demographic characteristics of groups

Characteristic	Single-task Group (n=13)	Dual-task Group (n=13)	P-value / %	Notes
Age (years)	28.00 (6.85)	31.30 (7.44)	0.54	Mean (SD)
Height (cm)	180.07 (5.07)	178.30 (5.37)	0.75	Mean (SD)
Weight (kg)	79.76 (13.33)	75.76 (10.81)	0.81	Mean (SD)
BMI (kg/m²)	24.75 (4.15)	23.87 (10.81)	0.39	Mean (SD)
Education (years)	14.77 (1.53)	15.08 (2.25)	0.61	Mean (SD)
Gender: Male (%)	13 (100%)	13 (100%)	—	n (%)
Gender: Female (%)	0 (0%)	0 (0%)	—	n (%)
Involved leg: Right (%)	8 (62%)	6 (46%)	—	n (%)
Involved leg: Left (%)	5 (38%)	7 (54%)	—	n (%)
Dominant leg: Right (%)	10 (77%)	10 (77%)	—	n (%)
Dominant leg: Left (%)	3 (23%)	3 (23%)	—	n (%)
Meniscus: Intact (%)	10 (77%)	10 (77%)	—	n (%)
Meniscus: Repaired (%)	3 (23%)	3 (23%)	—	n (%)

It is recommended that Table 1 be placed in the Methods section after Figure 1.

Table 2. Comparison SEBT[3]directions within and between group

	Dual-balance training			Single-balance training			
Variables	Before-intervention Mean (SD)	After-intervention Mean (SD)	P-value	Before-intervention Mean (SD)	After-intervention Mean (SD)	P-value	ANCOVA (between groups)
Anterior	64.37(7.37)	77.01 (5.67)	0.01	65.61 (5.22)	75.84(6.08)	0.01*	0.06
Anteromedial	64.46 (6.42)	76.76(4.10)	0.01	69.30 (5.21)	79.76 (5.49)	0.01*	0.75
Medial	66.84 (6.33)	80.35 (5.35)	0.01	67.46 (6.45)	80.07 (6.70)	0.01*	0.52
Posteromedial	68.07 (7.11)	82.92 (7.85)	0.01	70.53 (6.85)	82.02 (7.11)	0.01*	0.01*
Posterior	66.92 (6.80)	84.15 (7.59)	0.01	71.07 (6.90)	80.92 (7.37)	0.01*	0.01*
Posterolateral	62.30 (5.36)	77.56 (5.48)	0.01	65.92 (6.55)	78.15 (6.45)	0.01*	0.09
Lateral	63.23 (5.44)	76.69 (5.58)	0.01	64.84 (4.89)	75.92 (5.36)	0.01*	0.01*
Anterolateral	65.07 (5.18)	76.07 (5.90)	0.01	64.53 (5.47)	74.07(5.33)	0.01*	0.17

Statistical significance is indicated by *

The suggested location for Table 2 is in the Results section, immediately after the dynamic balance assessment paragraph.

[3] The star excursion balance test

Table 3. Comparison force plate parameters within and between groups

Variables	Dual-balance training Before-intervention Mean (SD)	Dual-balance training After-intervention Mean (SD)	Dual-balance training P - value	Single-balance training Before-intervention Mean (SD)	Single-balance training After-intervention Mean (SD)	Single-balance training P - value	ANCOVA (between groups)
NO.Mean,Vel[4]	4.22 (1.17)	3.613 (0.406)	0.03*	3.82 (1.02)	3.32 (0.41)	0.01*	0.72
NO.AP, SD-Vel[5]	1.87 (0.61)	1.514 (0.20)	0.36	1.648 (0.23)	1.55 (0.26)	0.07	0.61
NO.ML, SD Vel [6]	2,38 (0.18)	2.10 (0.19)	0.23	2.24 (0.29)	2.11 (0.32)	0.01*	0.68
NO. Sway Area[7]	8.83 (1.76)	7.26 (1.26)	0.01*	7.99 (1.37)	7.01 (0.93)	0.01*	0.92
BC.Mean,Vel[8]	4.30 (1.14)	3.53 (0.32)	0.06	3.78 (0.33)	3.53 (0.33)	0.02*	0.79
BC.AP, SD-Vel [9]	2.03 (0.47)	1.68 (0.10)	0.01*	1.89 (0.23)	1.62 (0.12)	0.01*	0.30
BC.ML, SD-Vel [10]	2..66 (0.42)	2.19 (0.27)	0.04*	2.45 (0.23)	2.26 (0.31)	0.01*	0.21
BC.SwayArea[11]	10.23 (2.81)	8.27 (2.30)	0.10	9.44 (2.13)	8.36 (1.32)	0.02*	0.46
ST.Mean,Vel[12]	4.63 (1.38)	3.95 (0.39)	0.09	4.29 (0.44)	3.94 (0.53)	0.09	0.96
ST.AP, SD-Vel [13]	2.20 (0.61)	1.80 (0.22)	0.02*	2.00 (0.08)	1.90 (0.35)	0.04*	0.71
ST.ML, SD-Vel [14]	2.89 (0.79)	2.47 (0.25)	0.04*	2.56 (0.28)	2.39 (0.38)	0.06	0.73
ST. Sway Area[15]	9.81 (1.96)	7.35 (1.77)	0.01*	9.15 (1.56)	7.84 (1.04)	0.01*	0.23

The suggested location for Table 3 is in the Results section, immediately after the Static balance assessment paragraph.

[4] No Cognitive Test, mean total velocity(cm/s)
[5] No Cognitive Test, standard deviation of velocity in Anterior-posterior (cm/s)
[6] No Cognitive Test, standard deviation of velocity in Medal-Lateral (cm/s)
[7] No Cognitive Test, sway area (cm2)
[8] Backward Counting Cognitive Test, mean total velocity(cm/s)
[9] Backward Counting Cognitive Test, standard deviation of velocity in Anterior-posterior (cm/s)
[10] Backward Counting Cognitive Test, standard deviation of velocity in Medial-Lateral (cm/s)
[11] Backward Counting Cognitive Test, sway area (cm2)
[12] Stroop Cognitive Test, mean total velocity(cm/s)
[13] Stroop Cognitive Test, standard deviation of velocity in Anterior-posterior (cm/s)
[14] Stroop Cognitive Test, standard deviation of velocity in Medial-Lateral (cm/s)
[15] Stroop Cognitive Test, sway area (cm2)

Table 4. Comparison Tegner and KOOS subscales within and between groups

	Dual-balance training			Single-balance training			ANCOVA (between groups)
variable	Before-Intervention Mean (SD)	After-Intervention Mean (SD)	P - value	Before-Intervention Mean (SD)	After-Intervention Mean (SD)	P - value	
Score	60.00 (5.19)	78.23 (5.41)	0.01*	61.76 (8.50)	77.15(5.27)	0.01*	**0.20**
KOOS-subscales							
Symptoms	79.09 (7.64)	92.92 (4.68)	0.01*	80.07(9.85)	90.30 (6.78)	0.01*	**0.19**
Pain	79.00 (10.76)	92.69 (4.83)	0.01*	81.00(11.57)	90.99(7.99)	0.01*	**0.37**
ADL	88.92 (5.10)	96.30 (2.05)	0.01*	62.77(10.63)	84.95(6.08)	0.01*	**0.48**
Sport	12.30 (7.25)	51.53 (15.73)	0.01*	16.90(7.76)	48.15(13.39)	0.01*	**0.27**
QOL	39.76 (10.13)	61.07 (11.76)	0.01*	43.92(17.76)	61.76(10.70)	0.01*	**0.79**
Tegner	2.08 (0.86)	4.23 (0.92)	0.01*	1.69 (0.85)	4.08 (1.18)	0.01*	**0.90**

The suggested location for Table 4 is in the Results section, immediately after the Functional disability assessment paragraph.