**Research Article**

# Comparative Analysis of Dual-Task and Single-Task Balance Exercises in Improving Static Balance in Individuals with Anterior Cruciate Ligament Reconstruction

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**Running Title:** Dual-task Balance Exercises in ACL Reconstruction

**Abstract**

**Background**: Various balance exercises have been employed to enhance functional stability and balance in individuals who have undergone anterior cruciate ligament (ACL) reconstruction. However, no study has explored the use of dual-task balance exercises for these patients. This study aims to compare the effects of dual motor task balance exercises and single-task exercises on the static balance indices of individuals with ACL reconstruction.

**Materials and Methods**: In a single-blind randomized controlled trial (IRCT20180925041138N2), 27 subjects who had undergone ACL reconstruction were randomly divided into two groups: dual-task and single-task balance exercises. Both groups performed their exercises three days a week for one month. Static balance indicators were assessed at the beginning and end of the treatment.

**Results**: The results demonstrated that after the treatment, there was a statistically significant decrease in various Center of Pressure variables, including mean displacement in the anterior-posterior and medial-lateral directions, total path length, mean velocity of displacement, root mean square of displacement, and velocity. Furthermore, the Knee Injury and Osteoarthritis Outcome Score (KOOS) significantly increased in both groups ($P < 0.05$). However, when comparing the two groups, no significant difference was observed after the treatment ($P > 0.05$).

**Conclusions**: Both dual-task and single-task motor exercises lead to improvements in static stability and knee function levels in patients who have undergone ACL reconstruction. It is noteworthy that the effectiveness of these exercise types does not significantly differ from each other.

**Keywords**: Anterior cruciate ligament deficiency, dual-task exercises, balance

## Introduction

Anterior cruciate ligament (ACL) reconstruction is a common procedure to address mechanical knee instability in individuals with ACL deficiency. While this surgery restores mechanical stability, it often results in proprioception impairment due to decreased sensory input from mechanoreceptors to the central nervous system (CNS). This impairment can negatively affect postural control, balance, and functional stability (1). Consequently, balance training plays a crucial role in the rehabilitation of individuals undergoing ACL reconstruction. Extensive evidence supports the inclusion of balance training in ACL reconstruction rehabilitation programs as it has the potential to enhance dynamic stability, improve postural balance, and restore functional ability by stimulating mechanoreceptors and increasing muscle spindle sensitivity in joint structures (2-5).

Existing evidence also highlights the presence of postural control impairment in both limbs following a unilateral ACL injury (6). This bilateral postural control disorder suggests the involvement of central factors (7). ACL injury is known to cause reorganization of the CNS due to changes in the ascending pathway to the CNS (8). Individuals with ACL reconstruction exhibit increased activity in the frontal lobe, secondary somatosensory region, and lingual gyrus during task completion when compared to their healthy counterparts. These areas involve complex integration of multiple sensory afferents, including vision, sensory processing, attention, and memory (8, 9). Electroencephalography (EEG) studies in individuals who have undergone ACL reconstruction have revealed alterations in sensory information processing, increased reliance on cortical information, and heightened attentional focus during task performance (10). In other words, ACL injury affects not only the peripheral musculoskeletal system but also the CNS, potentially leading to additional deficits (10, 11).

Recent studies have shown that directing attention toward external sources allows individuals to transfer motor skills and enhance the activity of subcortical autonomic areas (12). This promotes a higher level of automaticity in the movement system, resulting in more efficient performance and a more natural state (13). When a secondary task, whether motor or cognitive, is added to the primary task, such as balance, to direct attention to external sources, it is referred to as a dual-task state (14). Exercising in a dual-task condition can enhance the automaticity of the primary task, allowing the processing system to allocate fewer attentional resources for optimal performance of the primary task (15, 16). Following treatment, individuals who engage in dual-task exercises exhibit reduced neural activity in specific brain areas involved in dual-task performance, which can be attributed to reduced processing demands (13, 17, 18). Dual-task exercises expedite information processing, and evidence suggests that the response selection phase shortens with practice (19).

Some studies have suggested that performing balance exercises under dual conditions yields additional and superior effects compared to single balance exercises in improving individuals' balance levels. However, no study has explored the effects of dual-task balance exercises in postoperative rehabilitation programs for individuals with ACL reconstruction. Therefore, this study aims to investigate the impact of dual-task balance exercises on the static balance of these individuals.

## Method and materials

### Participants

A total of 49 individuals who had undergone ACL reconstruction surgery were referred to the physiotherapy clinic of the Rehabilitation Faculty at Tabriz University of Medical Sciences by an orthopedic surgeon. A qualified physiotherapist conducted assessments to determine eligibility based on inclusion and exclusion criteria. Inclusion criteria encompassed individuals who had undergone unilateral primary hamstring autograft ACL reconstruction, aged between 18 and 45 years. Exclusion criteria included a history of neurological, vestibular, vision, or other conditions affecting balance, additional knee ligament injuries or surgeries on the operated limb, previous injuries or surgeries to both ankle and hip joints, contralateral knee joints, and the spine. Additionally, participants with a pain level exceeding 3 on the Visual Analogue Scale (VAS) during balance tests were excluded. Eight individuals among the referrals chose to withdraw from the study, and twelve were excluded due to not meeting the inclusion criteria. Eventually, 29 individuals met the eligibility criteria, participated in the study, and provided informed consent for testing. However, during the course of the study, two participants dropped out. The study was conducted with a final sample size of 27 individuals, consisting of one female and 26 males, who were selected using a non-probability convenience sampling method. Group assignments were determined randomly by an individual not involved in the study, using random allocation software, with the allocation concealed from both the assessors and the participants (Fig. 1).

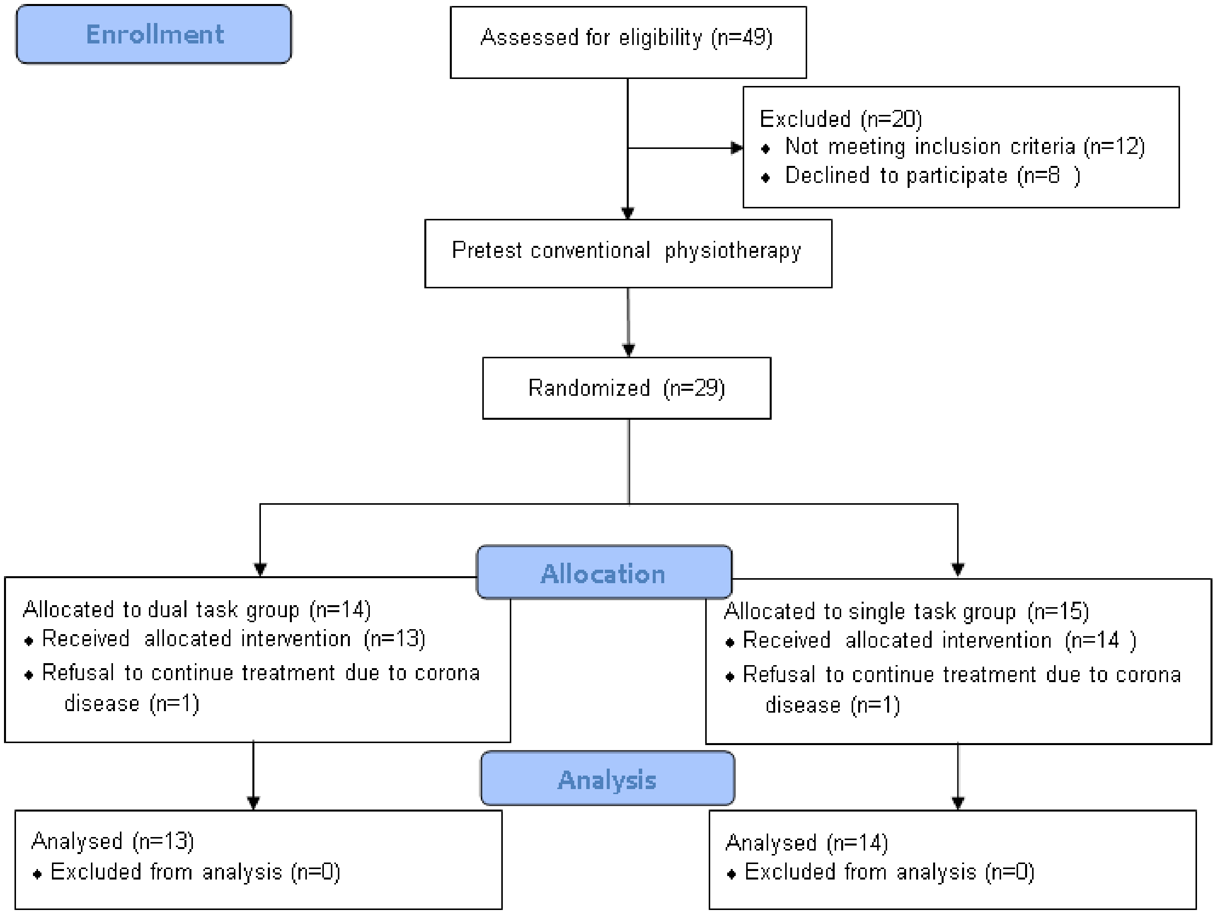


**Fig.1. Flow chart illustrating search and study selection**

## Study design

Our study follows a randomized controlled trial (RCT) design and adheres to the relevant CONSORT guidelines. It has been registered with the Iranian Registry of Clinical Trials under the registration number IRCT20180925041138N2. The study received approval from the ethics committee of Tabriz University of Medical Sciences (IR.TBZMED.REC.1397.946). To minimize bias, both the assessor physiotherapist and the data analyst were blinded to the group assignments.

**Procedure**

Initially, personal characteristics and information related to variables, including age, gender, height, weight, dominant leg, injured leg, and the time elapsed since the injury and surgery, were carefully recorded. (Tables 1 and 2).

**Table 1. Demographic characteristics of groups**

| Demographic data (Unite) | Single task group n=14 Mean (SD) | Dual task group n=13 Mean (SD) | P value |
|---|---|---|---|
| Age (yrs.) | 34.2 (6.20) | 29.92 (7.68) | 0.12 |
| Height (cm) | 173.29 (6.21) | 176.15 (5.09) | 0.20 |
| Weight (kg) | 75.06 (8.97) | 76.67 (9.55) | 0.65 |
| Body Mass Index ($kg/m^2$) | 24.94 (1.95) | 24.71 (2.88) | 0.81 |
| Injury and surgery interval (Month) | 6.5 (8.96) | 11.77 (22.92) | 0.64 |

**Table 2. Descriptive statistics of groups and comparing before intervention**

| Variable | | Single task group Number (%) | Dual task group Number (%) | P value |
|---|---|---|---|---|
| Gender | Male | 14 (100) | 12(92.3) | 0.48 |
| | Female | 0 (0) | 1(7.7) | |
| Involved knee | Right | 7 (50) | 3(23.1) | 0.23 |
| | Left | 7 (50) | 10(76.9) | |
| Menisci injury | Intact | 5 (35.7) | 4(30.8) | 1.00 |
| | Repaired | 9 (64.3) | 9(69.2) | |

The treatment plan for the participants consisted of two key components: conventional physiotherapy and balance exercises. All participants underwent conventional physical therapy prior to the allocation stage. Once the subjects achieved the necessary neuromuscular control to bear weight on the operated leg without experiencing pain or instability in the knee and demonstrated an active range of motion of 120 degrees of knee flexion, they were instructed to perform the static balance assessment. Additionally, they were asked to complete the Persian version of the Knee Injury and Osteoarthritis Outcome Score (KOOS) questionnaire (20).

Subsequently, participants were divided into two groups: the single-task (control) balance exercise group and the dual-task (intervention) balance exercise group. They then commenced the main balance exercise regimen, which spanned twelve sessions over the course of one month.

In the control group, participants received single-task balance exercises, while the intervention group engaged in dual motor task balance exercises. Following the completion of the exercise program, participants were once again asked to undergo the static balance assessment and to complete the KOOS questionnaire under the conditions that prevailed during their last session.

**Conventional physiotherapy**

Participants initiated the conventional physiotherapy program within a maximum period of one week following their surgical procedure, adhering to established references in the field of physical therapy (21-23). This comprehensive program encompassed electrical stimulation, cold therapy, and exercise therapy.

In the electrical stimulation component, transcutaneous electrical nerve stimulation (TENS) current with a frequency of 120 Hz and a pulse width of 60 μs was applied for 15 minutes. Electrodes were strategically positioned on both sides of the knee joint, with participants in a supine or long sitting position. The current intensity was set to a level that was well-tolerated by the patients (22). Additionally, functional electrical stimulation (FES) current was utilized with parameters including a 55 Hz frequency, 300 μs pulse width, a 4-second contraction hold time, and an 8-second rest time, all for a duration of 15 minutes. This was employed to strengthen the quadriceps muscle. The cathode electrode was positioned on the nerve in the upper third of the quadriceps muscle, and the anode electrode was placed in the muscle bulk, directed towards the vastus medialis oblique muscle. The current intensity was adjusted to the maximum tolerable limit for the patients (22). To address inflammation and joint effusion control, participants were instructed to apply an ice pack around the patella for 10 minutes both before and after their exercise sessions.

Therapeutic exercises were introduced in the very first session and encompassed a range of activities, including muscle strength and stretching exercises, as well as exercises aimed at improving knee joint range of motion (Table 3). During each session, new exercises or increased resistance were incorporated based on individual participant conditions and the physical therapist's assessment. Participants were encouraged to replicate these exercises at home, performing them twice a day to optimize their rehabilitation.

**Table 3. Conventional physiotherapy exercises**

| Type of Exercise | Number of Repetitions and Sets |
|---|---|
| Ankle Pumps | 30 repetitions in 3 sets |
| Quadriceps Setting in sitting position | 30 repetitions in 3 sets |
| Quadriceps Setting in standing position | 30 repetitions in 3 sets |
| Hamstring Setting | 30 repetitions in 3 sets |
| Gastrocnemius stretching | 5 repetitions for 30 seconds |
| Wall Slide | 30 repetitions in 3 sets |
| Heel slide | 30 repetitions in 3 sets |

| | |
|---|---|
| Knee flexion with Swiss Ball | 30 repetitions in 3 sets |
| SLR with hip flexion | 30 repetitions in 3 sets |
| SLR with hip abduction | 30 repetitions in 3 sets |
| SLR with hip adduction | 30 repetitions in 3 sets |
| Knee flexion in prone | 30 repetitions in 3 sets |
| Foot press | 30 repetitions in 3 sets |
| Terminal Knee Extension | 30 repetitions in 3 sets |
| Squat | 30 repetitions in 3 sets |
| Bicycle | 10 minutes with the least amount of resistance |
| Treadmill | 10 min forward and 5 min backward walking |
| Step | 30 repetitions in 3 sets |

**Knee Injury and Osteoarthritis Outcome Score (KOOS)**

The Knee Injury and Osteoarthritis Outcome Score (KOOS) is a validated tool designed to assess patient-relevant outcomes following knee injury. This self-administered questionnaire is structured into five sections and comprises a total of 42 questions, presented in the following sequence: pain (nine items), symptoms (seven items), daily activity performance (17 items), performance in sports and recreational activities (five items), and the quality of life (four items). Scores obtained from the questionnaire are converted to a 0–100 scale, where a score of zero indicates the presence of severe knee problems, and a score of 100 signifies an absence of knee problems (24, 25).

**Static balance test**

The static balance of all participants was evaluated using a foot pressure tool, specifically the zebris FDM pressure platform. This device has the capability to record the coordinates (X, Y) of the center of pressure (COP) with a sampling rate of 100.

For the static balance assessment, participants were instructed to stand barefoot on the FDM platform, separately on the operated and non-operated legs. During each leg test, participants maintained a specific posture, with their arms crossed on their chest, the weight-bearing knee flexed at 20 degrees, and the non-weight-bearing leg flexed at 45 degrees in both the knee and hip joints. The degrees of flexion were accurately controlled using a goniometer, and participants were required to sustain this posture during the test. If a subject was unable to maintain the described position and balance, the test was repeated. Each test session had a duration of 20 seconds, during which participants focused on a marked point located at eye level on the opposite wall at a distance of 1.4 meters. The test was performed three times for each participant, with a one-minute break given between repetitions to prevent fatigue. The average of the three repetitions was used for subsequent analysis.

**Balance exercises**

Upon random assignment to their respective groups, participants in the control group commenced single-task balance exercises, while those in the intervention group initiated dual motor task balance exercises, as outlined in Tables 4 and 5. These exercises were organized in an ascending order of difficulty, with the requirement that the previous exercise had to be completed successfully before progressing to the next one. Initially, all exercises on the balance boards were performed using both legs. As the participants' conditions improved, they transitioned to performing these exercises on the operated leg.

Each participant individually executed these exercises under the supervision of a physiotherapist, with three sessions per week over a duration of four weeks. Each session had a duration of 30 minutes. It's important to note that all exercises were conducted in the same environment setting for consistency among all participants.

**Table 4. Balance exercises related to the single-task group**

| |
|---|
| Standing on the ground with the operated leg |
| Standing on a two-directional balance board in the medial-lateral direction |
| Standing on the two-directional balance board in the anterior-posterior direction |
| Standing on the operated leg on a foam board with a thickness of 10.5 cm |
| Standing on a multi-directional balance board |
| Standing on a 10.5 cm thick foam board placed on a two-directional balance board, in the medial-lateral direction. |
| Standing on a 10.5 cm thick foam placed on a two-directional balance board, in the anterior-posterior direction |
| Standing on a 10.5 cm thick foam placed on a two-directional balance board, in the anterior-posterior direction |
| Standing on a 10.5 cm thick foam placed on a multi-directional balance board |

In the intervention group, the balance exercises were performed in the same order as the control group, besides that the participants had to perform another motor task with balance exercise simultaneously.

**Table 5. Balance exercises related to the dual task group**

| |
|---|
| Moving a ball between two hands alternately |
| Moving some water between glasses on hands alternately |
| following the lines of the special shapes embedded on the wall with a laser pointer |
| Catching a ball thrown toward subject |
| Throwing a tennis ball to the target marked on the wall |
| Passing a ball with non-operated leg |

**Statistical Analysis**

The software of the device used was unable to directly calculate all the variables for our study. Raw data extracted from the FDM pressure platform included coordinates of the center of pressure (COP) in both the X and Y axes at a sampling rate of 100. To address this, a knowledgeable medical engineer proficient in MATLAB software developed a computerized algorithm using MATLAB. This algorithm was capable of calculating various COP variables, including the average displacement of the COP (mm), the average displacement of the COP in both the anterior-posterior and medial-lateral directions (mm), the Root Mean Square (RMS) of the displacement of the COP, the total path of the COP (mm), the average velocity of the COP (mm/sec), the RMS of the velocity of the COP, and the elliptical area of the COP (mm2) based on the provided COP coordinates. The data from the MATLAB software was then imported into SPSS 25 software for the subsequent statistical analysis, maintaining a significance level of 0.05. To ensure the normality of data distribution, the Kolmogorov–Smirnov (K-S) test was employed. The analysis involved using the independent t-test to compare the averages of the variables between the two groups at both the study's outset and conclusion. Additionally, the paired t-test was applied to compare the averages within each group before and after the intervention. The ANCOVA test was utilized to control for the baseline effect of the variables. To investigate the relationship between the balance test variables and the scores of the KOOS questionnaire before and after the intervention, Pearson's correlation coefficient was calculated.

## Results

The results of the Kolmogorov–Smirnov (K-S) test indicated that the distribution of all variables in the study was found to be normal.

Regarding the within-group comparisons of static balance variables and questionnaire subscales, it was observed that in the control group, all static balance variables exhibited a significant reduction after engaging in balance exercises (P < 0.05), as presented in Table 6. In the dual-task motor group, all static balance variables displayed a significant decrease after the treatment (P < 0.05). The only exception was the elliptical area of the center of pressure (COP) (mm2), which did not exhibit a significant difference (P = 0.06), as indicated in Table 6.

**Table 6: Comparison of COP variables within and between groups**

| Variable | Single task | | | Dual task | | | ANCOVA (between group) |
|---|---|---|---|---|---|---|---|
| | Before intervention Mean (SD) | After intervention Mean (SD) | P value (within group) | Before intervention Mean (SD) | After intervention Mean (SD) | P value (within group) | |
| **Mean displace of COP (mm)** | 0.36 (0.05) | 0.30 (0.05) | 0.001 | 0.28 (0/03) | 0.24 (0.03) | 0.001 | 0.93 |
| **Mean displace of COP in AP (mm)** | 0.23 (0.04) | 0.19 (0.03) | 0.001 | 0.19 (0.02) | 0.16 (0.02) | 0.001 | 0.38 |
| **Mean displace of COP in ML (mm)** | 0.23 (0.02) | 0.19 (0.03) | 0.04 | 0.17 (0.01) | 0.15 (0.02) | 0.02 | 0.73 |
| **Total path of the COP (mm)** | 716.96 (101.13) | 593.68 (107.47) | 0.001 | 562.35 (67.35) | 488.99 (77.50) | 0.001 | 0.94 |
| **COP velocity (mm/s)** | 35.84 (5.05) | 29.65 (5.31) | 0.001 | 28.13 (3.36) | 24.46 (3.87) | 0.001 | 0.91 |
| **RMS of COP displacement** | 0.47 (0.06) | 0.38 (0.07) | 0.001 | 0.36 (0.03) | 0.31 (0.05) | 0.001 | 0.99 |
| **RMS of COP velocity** | 46.29 (6.61) | 37.90 (7.00) | 0.001 | 36.11 (3.81) | 31.22 (5.07) | 0.001 | 0.99 |
| **Elliptical area of COP ($mm^2$)** | 227.77 (5979) | 149.32 (39.69) | 0.001 | 175.50 (57.41) | 145.51 (14.03) | 0.06 | 0.80 |

COP: Center of Pressure, AP: Anterior-Posterior direction, ML: Medial-Lateral direction.

Regarding the questionnaire, it was found that in both groups, the balance exercises had a noteworthy impact, leading to a significant increase in the scores of all questionnaire subscales (P < 0.05), as shown in Table 7.

**Table 7: Comparison KOOS questionnaire subscales within and between groups**

| Variable | Single task | | | Dual task | | | P value (between group after intervention) |
|---|---|---|---|---|---|---|---|
| | Before intervention Mean (SD) | After intervention Mean (SD) | P value (within group) | Before intervention Mean (SD) | After intervention Mean (SD) | P value (within group) | |
| **Symptoms** | 57.29 (17.26) | 69.07 (17.09) | 0.01 | 59.46 (10.57) | 75.85 (11.21) | 0.001 | 0.23 |
| **Pain** | 60.36 (16.73) | 71.43 (18.71) | 0.04 | 58.92 (17.96) | 71.46 (13.99) | 0.001 | 0.99 |
| **Performance in ADLs** | 66.14 (16.38) | 80.86 (12.46) | 0.001 | 57.08 (19.34) | 73.46 (13.83) | 0.001 | 0.15 |
| **Performance in sports** | 14.64 (13.22) | 43.57 (19.05) | 0.001 | 18.46 (18.52) | 41.54 (23.39) | 0.001 | 0.80 |
| **Quality of life** | 64.28 (19.24) | 37.07 (17.26) | 0.001 | 28.62 (19.76) | 43.85 (16.50) | 0.001 | 0.30 |

KOOS: Knee Injury and Osteoarthritis Outcome Score, ADLs: Activities of daily living

The results of the between-group comparison of static balance variables and questionnaire subscales, using the ANCOVA test to neutralize the baseline effect, demonstrated that no significant differences (P > 0.05) were observed between the effects of the two types of intervention for static balance variables, as presented in Table 6. Furthermore, there were no statistically significant differences (P > 0.05) in questionnaire subscales between the two groups before and after the interventions, as shown in Table 7.

The results of the correlation analysis between static balance variables and questionnaire subscales revealed that in the group that engaged in dual motor task exercises, none of the questionnaire subscales exhibited a statistically significant correlation with any of the investigated static balance indicators before or after the interventions.

In contrast, within the single-task exercise group, the variable representing the elliptical area of the center of pressure (COP) (mm2) displayed a significant moderate negative correlation with the subscales related to sports activity and quality of life prior to the therapeutic interventions (r = -0.58, P < 0.05, and r = -0.54, P < 0.05, respectively). After the completion of the balance exercises, only the average displacement of the COP in the anterior-posterior direction (mm) demonstrated a significant relatively moderate positive correlation with the subscales associated with sports and recreational activities (r = 0.59, P < 0.05).

## Discussion

This study aimed to investigate the impact of dual motor task balance exercises on static balance and knee function, comparing it with the effects of single-task balance exercises. The study observed a general reduction in variables related to the displacement and speed of the Center of Pressure (COP) in both the dual motor task and single-task exercise groups after a period of exercise in individuals who had undergone ACL reconstruction surgery. This decrease in the COP's displacement and velocity parameters suggests an enhancement in balance, improved postural control, and increased stability (26-28).

Previous research by Souza et al. and Konak et al. in 2016 explored the effects of dual motor task and single-task exercises on individuals with ankle instability and osteoporosis, respectively. Their findings align closely with the results of the present study (17, 29). Evidence suggests that balance training on an unstable surface can heighten muscle spindle sensitivity through gamma motor neurons, thereby enhancing motor function and stability (30). Furthermore, training programs enable motor skills to operate automatically, reducing the demand for attention. This, in turn, allows individuals to allocate more attention capacity to other concurrent actions (31). It's widely acknowledged that as a task becomes more automated, the occurrence of errors decreases, and task execution becomes more aligned with natural functioning (13).

Based on the between-group results of this study, no significant difference was observed between dual motor and single-task balance exercises. Unfortunately, the authors could not find any prior studies that specifically investigated the impact of dual-task balance exercises on individuals with ACL reconstruction. However, in studies involving different subject groups, such as Onegh's research on individuals with functional ankle instability in 2020 (32), Konak's study on individuals with osteoporosis in 2016 (17), and Sinaei's investigation on elderly individuals in 2016 (33), no significant differences were identified between dual and single-task balance exercises.

In our study, similar to Onegh's research, balance assessments were not conducted under dual-task conditions while exercises were performed with the inclusion of a secondary task. It's plausible that if patients were assessed in a dynamic condition while concurrently performing a secondary task, the treatment group might have demonstrated a more substantial improvement compared to the control group. The transferability of the effects of dual-task exercises may be limited when evaluations are conducted solely in a single-task condition.

Additionally, the relatively small number of participants and the limited follow-up assessments post-treatment, akin to the study by Sinaei, may have influenced our results. Therefore, to achieve different outcomes in future research, it would be advisable to increase the number of participants and implement more extensive follow-up assessments after treatment.

In a study by Elhinidi et al. in 2016, it was reported that dual-task exercises had a more pronounced effect on balance compared to single tasks, particularly in children with hemiparesis. They conducted a 30-session training program, each lasting 1 hour, and observed a significant decrease in the swing area and swing rate in the dual-task group compared to the control group. Their hypothesis was that dual-task exercises lead to greater activation of new pathways in the cerebellum, sensory-motor cortex, and premotor cortex, as well as more substantial changes in brain neuroplasticity compared to the control group (18).

Similarly, Shin's study in 2014 reported a superior effect of dual motor task exercises on balance compared to single balance exercises in independent elderly women. The subjects underwent 45-minute balance exercise sessions, spanning a duration of 6 weeks. The study highlighted the simultaneous and complex involvement of various brain centers, including vision, somatosensory, vestibular, and attention centers, in dealing with gravity, body movements, and the environment, which contributed to the superiority of dual-task exercises (34).

In contrast to our study, the two aforementioned studies employed a longer treatment duration. It appears that dual-task exercises may require more consistent repetition to achieve their full effectiveness. Therefore, despite the results of this study, the authors believe in the greater potential and efficacy of dual-task balance exercises. They suggest that the dual-task group could yield superior results compared to the single-task group if the number of treatment sessions and the overall treatment duration were increased.

Regarding the questionnaire, the results of this study demonstrate an increase in the scores of the Knee Injury and Osteoarthritis Outcome Score (KOOS) questionnaire in both the dual and single-task exercise groups. It's worth noting that some studies interpret an increase in these questionnaire scores as an indicator of improved knee function (24, 25). In the present study, a statistically significant increase in post-treatment scores was observed, suggesting an overall improvement in knee function among the participants. However, it's important to highlight that the dual-task balance exercise did not exhibit a superior effect on questionnaire scores, and consequently, knee function did not significantly differ between the two groups.

Furthermore, there was generally no significant correlation between static balance variables and the questionnaire subscales. A similar finding was reported in a study conducted by Wang et al. in 2021, where no correlation was identified between static balance variables and the questionnaire in patients who had undergone total knee replacement surgery. They emphasized that an improvement in pain perception and knee function does not necessarily indicate an improvement in postural control performance after treatment (35).

## Conclusion

In conclusion, both dual motor and single-task balance exercises have demonstrated the ability to enhance static balance indices and reduce levels of knee functional disability. However, this study did not find a significant superiority of one exercise type over the other over the course of 12 sessions within a one-month timeframe.

## Limitations

Several limitations of this study should be acknowledged. First, post-treatment follow-up assessments were not conducted to evaluate the durability of the treatment effects, which could provide valuable insights into the long-term impact of these exercises. Secondly, the sample size in this study was relatively small, which may have contributed to the lack of a significant difference in results between the two exercise groups. The short duration of the treatment plan could also be a limiting factor, as a longer exercise regimen may yield more pronounced differences. Lastly, it is worth noting that the majority of the participants in this study were men, which may restrict the generalizability of the results to the broader population.

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**Authors' contributions**

**Conceptualization, study design and final approval:** All authors; **Data collection:** Fatemeh Oraei Eslami, Masumeh Hallaj Mazidluie; **Data analysis and data interpretation:** Fatemeh Oraei Eslami, Jalal Ahadi, Tabassom Ghanavati; **Drafting the manuscript:** Fatemeh Oraei Eslami, Jalal Ahadi

**Conflict of interest**

The authors declared no conflict of interest.

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