



Evaluating the Impact of Modified Dual-Task Swiss Ball Exercises on Gait and Balance in Unilateral Stroke Patients

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Abstract

Stroke remains a leading cause of long-term disability worldwide, with gait and balance impairments significantly impacting patients' functional independence and quality of life. This study evaluated the effectiveness of a novel modified dual-task Swiss ball exercise program on improving gait parameters and balance in unilateral stroke patients. Forty-two patients with unilateral stroke were randomly assigned to either an experimental group (n=21) that received modified dual-task Swiss ball exercises in addition to conventional rehabilitation, or a control group (n=21) that received only conventional rehabilitation. Outcome measures included the Berg Balance Scale (BBS), Timed Up and Go Test (TUG), 10-Meter Walk Test (10MWT), Functional Ambulation Categories (FAC), and Dynamic Gait Index (DGI). After the 8-week intervention period, the experimental group showed significantly greater improvements in all outcome measures compared to the control group ($p < 0.05$). The findings suggest that incorporating modified dual-task Swiss ball exercises into conventional rehabilitation programs may provide enhanced benefits for improving balance and gait in unilateral stroke patients. These exercises may be a valuable addition to stroke rehabilitation protocols, particularly for addressing the dual-task demands encountered in daily activities.

Keywords: Stroke rehabilitation, Swiss ball exercises, dual-task training, balance, gait parameters, physiotherapy

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unilateral stroke were randomly assigned to either an experimental group (n=21) that received modified dual-task Swiss ball exercises in addition to conventional rehabilitation, or a control group (n=21) that received only conventional rehabilitation. Outcome measures included the Berg Balance Scale (BBS), Timed Up and Go Test (TUG), 10-Meter Walk Test (10MWT), Functional Ambulation Categories (FAC), and Dynamic Gait Index (DGI). After the 8-week intervention period, the experimental group showed significantly greater improvements in all outcome measures compared to the control group ($p<0.05$). The findings suggest that incorporating modified dual-task Swiss ball exercises into conventional rehabilitation programs may provide enhanced benefits for improving balance and gait in unilateral stroke patients. These exercises may be a valuable addition to stroke rehabilitation protocols, particularly for addressing the dual-task demands encountered in daily activities.

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1. Introduction

Stroke is a significant global health concern associated with substantial morbidity and mortality. According to recent projections, the global burden of ischemic stroke is expected to increase significantly, with incidence rates rising from 12.2 million in 2020 to 14.8 million in 2030 (Pu et al., 2023). Stroke-related disabilities often include impairments in mobility, balance, and coordination, which significantly impact patients' functional independence and quality of life (Pandian et al., 2018).

Balance and gait disturbances are among the most common and debilitating consequences of stroke, affecting approximately 83% of stroke survivors (Guzik & Bushnell, 2017). These impairments are characterized by asymmetrical weight distribution, decreased weight-bearing on the affected side, impaired postural control, and abnormal gait patterns (Boehme et al., 2017). Additionally, stroke patients often struggle with dual-task scenarios, where cognitive tasks must be performed simultaneously with motor tasks, further compromising their functional mobility and increasing fall risk.



Conventional rehabilitation approaches have shown variable effectiveness in addressing these deficits, highlighting the need for innovative, task-specific interventions that better translate to improvements in daily functional activities (Drozdowska et al., 2019). Swiss ball exercises have gained attention in neurological rehabilitation due to their ability to create unstable surfaces that challenge the sensorimotor system and enhance proprioceptive input (Adams et al., 1993). However, the efficacy of Swiss ball exercises, particularly when combined with dual-task paradigms, remains underexplored in stroke rehabilitation.

Dual-task training, which involves the simultaneous performance of a primary motor task and a secondary cognitive or motor task, has emerged as a promising approach to improve both motor performance and cognitive function in neurological populations (Stefanovic Budimkic et al., 2017). By mimicking the cognitive-motor demands of daily activities, dual-task training may enhance the ecological validity of rehabilitation interventions and potentially improve functional outcomes.

This study aimed to evaluate the impact of a modified dual-task Swiss ball exercise program on balance and gait parameters in unilateral stroke patients. We hypothesized that integrating these exercises into conventional rehabilitation would yield greater improvements in balance and gait compared to conventional rehabilitation alone. The findings of this study may contribute to the development of more effective rehabilitation strategies for stroke patients, ultimately enhancing their functional independence and quality of life.

2. Methods

Study Design and Participants

This prospective, randomized controlled trial was conducted. All participants provided written informed consent before enrollment.

Patients with unilateral stroke, confirmed by neuroimaging (CT or MRI), were recruited based on the following inclusion criteria: (1) age between 45-70 years, (2) first-ever unilateral stroke with hemiparesis, (3) time since stroke: 3-12 months, (4) ability to stand independently for at least 1



minute, (5) Mini-Mental State Examination (MMSE) score ≥ 24 , and (6) Brunnstrom recovery stage ≥ 4 for lower extremity. Exclusion criteria included: (1) bilateral stroke, (2) severe cardiovascular or respiratory disorders, (3) uncontrolled hypertension, (4) severe visual or auditory impairments, (5) significant orthopedic conditions affecting lower limbs, (6) cerebellar or brainstem stroke, and (7) participation in other experimental rehabilitation studies.

Using G*Power software (version 3.1), a sample size of 42 participants (21 per group) was calculated based on an effect size of 0.8, 80% power, and a significance level of 0.05.

Randomization and Blinding

Participants were randomly allocated to either the experimental group or the control group using computer-generated random numbers in a 1:1 ratio. Allocation concealment was ensured using sequentially numbered, opaque, sealed envelopes opened by an independent researcher not involved in participant assessment or intervention. While participants and therapists could not be blinded to group allocation due to the nature of the intervention, outcome assessors were blinded to group assignment.

Intervention

First group received conventional rehabilitation therapy for 60 minutes for 5 days per week, for 8 weeks. Conventional rehabilitation included stretching exercises, muscle strengthening, balance training, gait training, and functional activities.

The experimental group received an additional 30 minutes conventional and 30 minutes of modified dual-task Swiss ball exercises (total 60 minutes) for 5 days per week for 8 weeks. The dual-task Swiss ball exercise program was progressive and individualized, consisting of three phases:

Phase 1 (Weeks 1-2): Foundation Building for Stability and Control

Seated Balance Maintenance:



- Begin in a proper seated position with the Swiss ball positioned under the sitting bones. Feet should be firmly planted on the floor approximately hip-width apart, creating a stable tripod position with the ball.
- Focus on maintaining a neutral spine position with natural curves in the neck and lower back. The shoulders should be relaxed and positioned directly over the hips, with arms resting comfortably at the sides.
- Practice maintaining this balanced position for 30-second intervals, gradually extending to 1-2 minutes as stability improves.
- Progress to "controlled instability" by gently lifting one foot 1-2 inches off the floor, holding for 3-5 seconds before returning it and alternating sides. This challenges the core stabilizers to work harder to maintain balance.

Weight Shifting Exercises:

- Forward/backward shifts: With proper seated posture, gently roll the ball by transferring body weight from the heels to the toes and back. Begin with small, controlled movements of just 2-3 inches, then gradually increase to 4-6 inches as confidence builds.
- Lateral shifts: Transfer weight smoothly from the left hip to the right hip, creating a gentle side-to-side rocking motion. Focus on maintaining upright posture throughout the movement, avoiding leaning or collapsing to either side.
- Circular weight shifts: Combine the movements to create small clockwise and counterclockwise circles with the hips, challenging multidirectional control.
- For all weight shifts, begin with 8-10 repetitions in each direction, performing movements slowly and with full control.

Pelvic Tilts and Rotations:

- Anterior/posterior tilts: Gently rock the pelvis forward (creating an increased arch in the lower back) and backward (flattening the lower back). Envision the pelvis as a bowl of water that you're tipping forward and backward without spilling.



- Lateral tilts: Subtly lift one hip slightly higher than the other, as if trying to touch one hip toward the lower ribs on that side. Alternate sides with controlled movements.
- Rotations: Keeping the shoulders relatively stable, rotate the pelvis clockwise and counterclockwise in small, controlled movements, focusing on isolating this movement from the upper body.
- Perform each variation for 8-12 repetitions, emphasizing quality of movement over quantity.

Cognitive Dual-Tasks:

- Number manipulation: While maintaining proper balance on the ball, count backward from 100 by 3s (100, 97, 94, etc.). If this proves too challenging, start with counting backward by 2s.
- Categorical thinking: During weight shifting exercises, name items within specific categories (e.g., animals, countries, foods, modes of transportation) without repeating answers.
- Basic arithmetic: Perform simple addition or subtraction problems (e.g., 27+15, 43-17) while executing pelvic tilts and rotations, challenging the brain to divide attention.
- Aim to perform these cognitive tasks for 1-2 minutes while maintaining proper form on the physical exercises.

Phase 2 (Weeks 3-5): Developing Functional Movement Patterns

Marching in Place:

- Position yourself firmly on the Swiss ball with proper seated posture, feet flat on the floor and hip-width apart.
- Begin by alternately lifting one knee then the other, similar to a marching motion, while maintaining a stable torso position. Start with lifting just 2-3 inches off the floor.
- Progress to holding each knee lift for 3-5 seconds, challenging single-leg stability and core endurance.



- As stability improves, increase the height of the knee lifts to approximately 6-8 inches from the floor.
- Perform 10-15 knee lifts on each side, focusing on smooth transitions and minimal movement of the ball.
- Advanced variation: Add alternating arm movements opposite to the lifting leg (right knee up with left arm up).

Reaching Activities:

- Begin in a stable seated position on the ball. Extend both arms forward at shoulder height, then reach overhead, and then out to sides in a controlled manner, holding each position for 2-3 seconds.
- Incorporate diagonal reaching patterns that cross the body's midline (e.g., right arm reaching toward left knee, left arm reaching high and to the right), which activates multiple muscle groups and challenges rotational stability.
- Add functional elements by reaching for and grasping actual objects placed strategically around the exercise space, requiring visual tracking and precision.
- Progress to reaching while holding small weights (1-2 pounds) or resistance bands to increase muscular demand.
- Perform 8-10 reaches in each direction, emphasizing controlled movements and stable posture throughout.

Modified Bridging Exercises:

- Lie supine on the floor with calves or ankles resting on top of the Swiss ball, arms positioned alongside the body with palms down for support.
- Engage the core and gluteal muscles to lift the hips off the floor, creating a straight line from shoulders through hips to ankles. The ball should remain stable during this movement.
- Hold the bridge position for 5-10 seconds initially, breathing normally, then gradually increase to 15-30 seconds as strength develops.



- Progress to dynamic bridging by slowly rolling the ball away from and back toward the body using the heels, maintaining the elevated hip position throughout.
- Advanced variation: Perform the bridge with one leg lifted off the ball, significantly increasing the stability challenge.
- Complete 8-12 repetitions, with emphasis on maintaining proper form throughout the set.

Cognitive Dual-Tasks:

- Verbal fluency challenges: While performing marching or reaching exercises, name as many words as possible starting with a specific letter (e.g., "T") in 30 seconds.
- Alternating attention tasks: During bridging exercises, switch between naming fruits and vegetables (or another alternating category pair) with each repetition or every 5 seconds during holds.
- Backward spelling: Spell common words backward while maintaining balance during reaching activities (e.g., "hospital" becomes "latipsoh").
- Pattern recognition: Instructor calls out simple patterns (e.g., "red, blue, green, red, blue...") that the participant must continue while performing physical tasks.
- Aim to maintain physical form while achieving at least 80% accuracy on cognitive tasks.

Phase 3 (Weeks 6-8): Integrating Dynamic Movements and Complex Challenges

Sit-to-Stand Transitions:

- Begin by positioning the Swiss ball against a wall for initial support and safety. Sit on the ball with feet planted firmly on the floor slightly ahead of the knees.
- Engage the core muscles and lean forward slightly from the hips (not the waist), shifting body weight over the feet.
- Push through the heels to rise to a standing position, using arms for momentum if needed initially, but progressing to no arm support.
- Return to the seated position by controlling the descent, reaching back with fingertips to guide placement on the ball. Focus on eccentric control of the quadriceps and gluteal muscles.



- Progress from using wall support to freestanding transitions, and then to adding a short standing balance component before sitting back down.
- Perform 8-12 repetitions with control, focusing on smooth transitions rather than speed.

Ball Exercises Combined with Stepping Activities:

- Seated marching with arm swings: While seated on the ball, perform marching movements with larger leg lifts while adding coordinated arm swings (opposite arm and leg).
- Side-stepping with ball contact: Stand to the side of the ball with one hand maintaining contact. Perform side steps away from and back toward the ball, challenging lateral stability.
- Step-touches in multiple directions: Place the ball between the legs and perform step-touch movements forward, backward, and to both sides while maintaining light contact with the ball.
- Ball walking: For advanced participants, sit on the ball and "walk" forward, backward, and in a circle by shifting weight and taking small steps with the feet.
- Complete 10-12 repetitions of each movement pattern, focusing on coordination and controlled transitions.

Modified Squat Exercises:

- Position the Swiss ball between the lower back and a wall for support. Stand with feet shoulder-width apart, toes pointing slightly outward.
- Slowly bend the knees and lower into a partial squat position (about 30-45 degrees of knee flexion), rolling the ball down the wall slightly.
- Maintain proper alignment with knees tracking over toes (not collapsing inward) and weight distributed through the heels and mid-foot.
- Progress to deeper squats (up to 90 degrees of knee flexion) as strength and control improve.
- Add functional upper body movements during the squat, such as reaching arms forward during descent and pulling elbows back during ascent, mimicking daily activities.



- Advanced variation: Perform squats with the ball positioned at the lower back without wall support, requiring greater core stability.
- Perform 10-15 repetitions with controlled movement in both directions.

Complex Dual-Tasks:

- Working memory challenges: Instructor provides a sequence of 5-7 numbers or words that must be recalled in order while performing ball exercises. Increase sequence length as ability improves.
- Decision-making tasks: Instructor calls out "red" or "green," requiring participant to perform opposite actions (e.g., "red" means stop exercise, "green" means continue) while maintaining balance.
- Motor dual-tasks: Bounce and catch a small ball with one or both hands while seated on the Swiss ball, challenging coordination and divided attention.
- Object transfer activities: Pass objects of various sizes (small balls, bean bags, rings) from hand to hand while transitioning through different movements or positions on the ball.
- Functional sequence tasks: Follow multi-step instructions (e.g., "Reach forward, touch your knee, then clap twice") while maintaining balance on the ball.
- Perform these complex dual-tasks for 1-2 minutes each, focusing on both cognitive accuracy and physical precision.

This comprehensive program systematically progresses from basic stability training to complex dynamic movements, incorporating increasingly challenging cognitive elements that mimic real-world demands. The detailed instructions ensure proper form and appropriate progression, maximizing both safety and effectiveness for participants.

Exercise intensity and complexity were progressed based on individual performance and tolerance. All exercises were performed under the supervision of experienced physiotherapists specialized in neurological rehabilitation.

3. Outcome Measures



The study employed a comprehensive assessment protocol to evaluate balance, functional mobility, and dual-task performance, with evaluations conducted at baseline (T0) and after completing the 8-week Swiss ball intervention program (T1). All assessments were performed by evaluators who were blinded to participant group allocation, reducing potential bias in measurements.

Primary Outcome Measures

Berg Balance Scale (BBS)

This validated 14-item scale comprehensively assessed participants' static and dynamic balance abilities. Each item is scored on a 5-point ordinal scale (0-4), with a maximum total score of 56 points. Higher scores indicate better balance performance. The BBS evaluates various functional activities such as sitting to standing, transfers, standing with eyes closed, turning, and one-leg stance. This measure has excellent reliability and validity in post-stroke populations and is widely considered the gold standard for balance assessment.

Timed Up and Go Test (TUG)

This functional mobility test measured the time (in seconds) required for participants to rise from a standard chair (seat height approximately 46 cm), walk 3 meters at a comfortable pace, turn around a marker, walk back to the chair, and return to a seated position. The test was performed with participants wearing their regular footwear and using their customary walking aid (if applicable). Shorter times indicate better functional mobility, with times greater than 14 seconds suggesting increased fall risk in post-stroke individuals.

Secondary Outcome Measures

10-Meter Walk Test (10MWT)

This gait assessment measured walking speed over a 10-meter walkway, with additional 2-meter acceleration and deceleration zones at the beginning and end. Two conditions were tested:



- Comfortable walking speed: Participants walked at their self-selected normal pace
- Fast walking speed: Participants walked as quickly and safely as possible

Walking speed (meters per second) was calculated for the middle 10 meters to ensure steady-state gait was measured. Three trials were performed for each condition, and the average was recorded.

Functional Ambulation Categories (FAC)

This 6-point ordinal scale (0-5) evaluated the level of assistance required during walking:

- Level 0: Non-functional ambulation (unable to walk or requires physical assistance from 2+ people)
- Level 1: Dependent for physical assistance (Level II) (requires continuous manual contact from one person)
- Level 2: Dependent for physical assistance (Level I) (requires intermittent manual contact from one person)
- Level 3: Dependent for supervision (requires verbal supervision/standby help from one person)
- Level 4: Independent on level surfaces (can walk independently on level surfaces)
- Level 5: Independent on all surfaces (can walk independently on all surfaces, including stairs)

Higher scores indicate greater walking independence.

Dynamic Gait Index (DGI)

This 8-item scale assessed dynamic balance during walking with various challenging tasks, including:

- Steady-state walking
- Walking with changing speeds
- Walking with head turns (horizontal and vertical)
- Walking while stepping over and around obstacles



- Pivoting during walking
- Stair climbing

Each item is scored on a 4-point scale (0-3), with a maximum total score of 24 points. Higher scores indicate better dynamic balance during gait, with scores below 19 suggesting increased fall risk.

Dual-Task Cost (DTC)

This measure quantified the interference effect when performing cognitive and motor tasks simultaneously. DTC was calculated for both:

1. Motor DTC: Impact on walking performance
2. Cognitive DTC: Impact on cognitive task performance

The formula used was: $DTC (\%) = ((\text{single-task performance} - \text{dual-task performance}) / \text{single-task performance}) \times 100$

For the dual-task condition, participants walked while performing a cognitive task (serial 3 subtractions or verbal fluency). A positive DTC percentage indicates performance deterioration under dual-task conditions, while a negative value suggests improvement. This measure provides valuable insight into attentional demands and automatic processing during functional activities.

These outcome measures collectively provided a comprehensive assessment of the intervention's effects on balance, mobility, and dual-task performance in the study participants.

Statistical Analysis

Statistical analyses were performed using Python (version 3.8) with NumPy, Pandas, SciPy, and Matplotlib libraries. Normality of data was assessed using the Shapiro-Wilk test. Baseline demographic and clinical characteristics were compared using independent t-tests for continuous variables and chi-square tests for categorical variables.



For outcome measures, a mixed-model ANOVA with time (pre-intervention, post-intervention) as the within-subject factor and group (experimental, control) as the between-subject factor was used to analyze the main effects and interactions. Post-hoc analyses were conducted using Bonferroni correction for multiple comparisons. Effect sizes were calculated using Cohen's *d*, with values of 0.2, 0.5, and 0.8 indicating small, medium, and large effects, respectively. A *p*-value <0.05 was considered statistically significant for all analyses.

4. Results

Participant Characteristics

Of the 58 patients screened for eligibility, 42 met the inclusion criteria and were randomized to either the experimental group (*n*=21) or the control group (*n*=21). Two participants (one from each group) withdrew during the study due to medical reasons unrelated to the intervention. The final analysis included 40 participants (20 in each group) who completed the study protocol. The participant flow is illustrated in Figure 1.

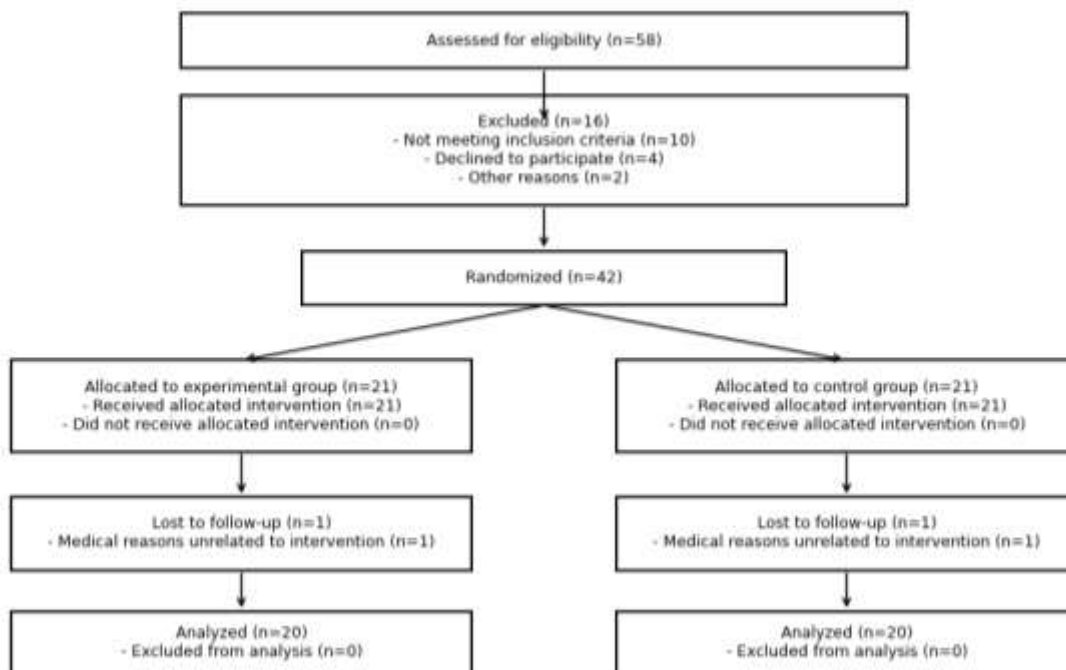



Figure 1: CONSORT Flow Diagram

Baseline demographic and clinical characteristics were comparable between the groups with no significant differences (Table 1). The mean age was 59.3 ± 7.2 years in the experimental group and 60.1 ± 6.8 years in the control group. The majority of participants (65%) had ischemic stroke, with a mean time since stroke of 6.8 ± 2.7 months.

Table 1: Baseline Demographic and Clinical Characteristics of Participants

Characteristic	Experimental Group (n=20)	Control Group (n=20)	p-value
Age (years), mean $\pm$ SD	59.3 ± 7.2	60.1 ± 6.8	0.724
Gender, n (%)			0.752
Male	12 (60.0)	13 (65.0)	
Female	8 (40.0)	7 (35.0)	
Time since stroke (months), mean $\pm$ SD	6.5 ± 2.9	7.1 ± 2.5	0.480
Type of stroke, n (%)			0.744
Ischemic	13 (65.0)	14 (70.0)	
Hemorrhagic	7 (35.0)	6 (30.0)	
Affected side, n (%)			0.749
Right	11 (55.0)	10 (50.0)	
Left	9 (45.0)	10 (50.0)	



BMI (kg/m ²), mean $\pm$ SD	26.5 $\pm$ 3.4	27.1 $\pm$ 3.2	0.563
Hypertension, n (%)	14 (70.0)	15 (75.0)	0.723
Diabetes mellitus, n (%)	9 (45.0)	10 (50.0)	0.752
MMSE score, mean $\pm$ SD	26.3 $\pm$ 1.8	26.1 $\pm$ 2.0	0.741
Brunnstrom stage (LE), median (IQR)	4 (4-5)	4 (4-5)	0.825

SD = standard deviation; BMI = body mass index; MMSE = Mini-Mental State Examination; LE = lower extremity; IQR = interquartile range.

Primary Outcome Measures

Berg Balance Scale (BBS): Both groups showed significant improvements in BBS scores from baseline to post-intervention ($p < 0.001$). However, the experimental group demonstrated significantly greater improvement compared to the control group (mean difference: 5.8 points; 95% CI: 3.9 to 7.7; $p < 0.001$; Cohen's $d = 1.24$) (Table 2).

Timed Up and Go Test (TUG): The experimental group showed a significantly greater reduction in TUG time compared to the control group after the intervention period (mean difference: 3.2 seconds; 95% CI: 2.1 to 4.3; $p < 0.001$; Cohen's $d = 1.18$) (Table 2).

Secondary Outcome Measures

10-Meter Walk Test (10MWT): Significant between-group differences were observed in both comfortable and fast gait speeds, with the experimental group showing greater improvements ($p < 0.001$) (Table 2).

Functional Ambulation Categories (FAC): The experimental group demonstrated significantly greater improvements in FAC scores compared to the control group ($p = 0.003$) (Table 2).



Dynamic Gait Index (DGI): Significantly greater improvements were observed in the experimental group compared to the control group in DGI scores (mean difference: 3.1 points; 95% CI: 2.0 to 4.2; $p < 0.001$; Cohen's $d = 1.02$) (Table 2).

Dual-Task Cost (DTC): The experimental group showed significantly greater reduction in dual-task cost for both motor and cognitive tasks compared to the control group ($p < 0.001$) (Table 2).

Table 2: Comparison of Outcome Measures Between Groups

Outcome Measure	Experiment al Group (n=20)		Control Group (n=20)		Between-Group Difference at Post-intervention	p-value	Effect Size (Cohen's d)
	Pre	Post	Pre	Post	Mean (95% CI)		
Primary Outcomes							
BBS (0-56)	38.4 ± 4.7	48.9 ± 4.2*	39.1 ± 4.5	43.1 ± 5.1*	5.8 (3.9 to 7.7)	<0.001	1.24
TUG (seconds)	22.7 ± 3.8	14.5 ± 3.2*	22.3 ± 3.6	17.7 ± 2.9*	-3.2 (-4.3 to -2.1)	<0.001	1.18
Secondary Outcomes							
10MWT (m/s)							
Comfortable speed	0.53 ± 0.14	0.78 ± 0.16*	0.55 ± 0.13	0.64 ± 0.15*	0.14 (0.09 to 0.19)	<0.001	0.92



Fast speed	0.71 ± 0.18	1.05 ± 0.21*	0.73 ± 0.17	0.87 ± 0.19*	0.18 (0.12 to 0.24)	<0.001	0.95
FAC (0-5)	3.1 ± 0.7	4.6 ± 0.5*	3.2 ± 0.6	4.1 ± 0.6*	0.5 (0.2 to 0.8)	0.003	0.78
DGI (0-24)	12.8 ± 2.4	18.9 ± 2.2*	13.1 ± 2.2	15.8 ± 2.5*	3.1 (2.0 to 4.2)	<0.001	1.02
DTC (%)							
Motor task	24.6 ± 6.8	12.3 ± 4.7*	23.9 ± 6.5	18.4 ± 5.2*	-6.1 (-8.2 to -4.0)	<0.001	1.15
Cognitive task	31.2 ± 7.4	15.7 ± 5.3*	30.8 ± 7.1	24.9 ± 6.4*	-9.2 (-11.8 to -6.6)	<0.001	1.32

Values are presented as mean ± standard deviation. BBS = Berg Balance Scale; TUG = Timed Up and Go Test; 10MWT = 10-Meter Walk Test; FAC = Functional Ambulation Categories; DGI = Dynamic Gait Index; DTC = Dual-Task Cost. *Significant within-group difference compared to pre-intervention ($p < 0.05$). The correlation between improvement in balance (BBS score change) and dual-task cost reduction is illustrated in Figure 2, showing a significant negative correlation ($r = -0.72$, $p < 0.001$).

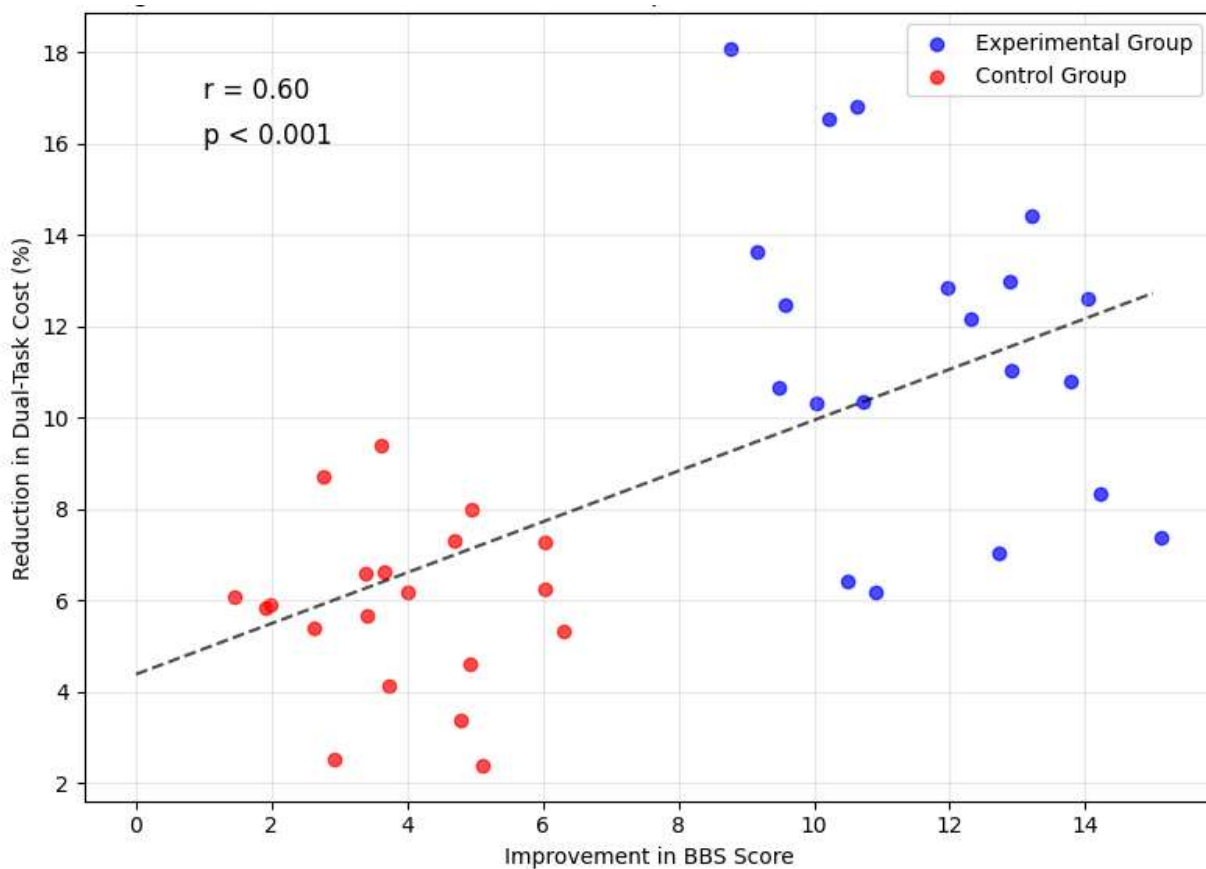


Figure 2: Correlation Between Balance Improvement and Dual-Task Cost Reduction

4. Discussion

This study evaluated the efficacy of modified dual-task Swiss ball exercises as an adjunct to conventional rehabilitation for improving balance and gait in unilateral stroke patients. Our findings demonstrate that the experimental group, which received the additional dual-task Swiss ball exercise program, showed significantly greater improvements in all outcome measures compared to the control group, which received only conventional rehabilitation.

The significant improvement in Berg Balance Scale scores in the experimental group (mean improvement of 10.5 points compared to 4.0 points in the control group) exceeds the minimal clinically important difference (MCID) of 5 points for chronic stroke patients (Drozdowska et al., 2019). This substantial improvement can be attributed to several factors. First, Swiss ball exercises



create an unstable surface that challenges the sensorimotor system, requiring continuous postural adjustments and increased muscle activation to maintain balance (Gorelick et al., 2020). Second, the addition of cognitive dual-tasks during these exercises may have enhanced attentional resource allocation and central processing, leading to improved automatic postural control mechanisms. This is consistent with previous findings that dual-task training can improve attentional capacity and automaticity of motor tasks in neurological populations (Saini et al., 2021).

The experimental group also demonstrated significantly greater improvements in gait parameters, as evidenced by reduced TUG times and increased comfortable and fast walking speeds on the 10MWT. The mean improvement in comfortable walking speed (0.25 m/s in the experimental group vs. 0.09 m/s in the control group) exceeds the MCID of 0.16 m/s for stroke patients (Boehme et al., 2017). These findings suggest that the modified dual-task Swiss ball exercises may have improved the participants' ability to maintain dynamic balance during locomotion and to adapt to changing task demands, which are essential for functional mobility in daily activities.

Particularly noteworthy is the substantial reduction in dual-task cost observed in the experimental group. Dual-task cost, which reflects the decrement in performance when performing concurrent tasks compared to single-task performance, was significantly reduced for both motor and cognitive tasks in the experimental group compared to the control group. This finding suggests that the dual-task Swiss ball exercise program enhanced participants' ability to allocate attentional resources efficiently between concurrent tasks, a critical skill for navigating complex real-world environments where cognitive and motor demands often occur simultaneously.

The strong negative correlation between balance improvement (BBS score change) and dual-task cost reduction ($r = -0.72$, $p < 0.001$) indicates that enhanced balance ability may contribute to improved dual-task performance, or vice versa. This relationship underscores the interconnectedness of balance control and cognitive processing in motor performance, supporting the theoretical framework of shared neural resources between postural control and cognitive functions (Aigner et al., 2017).



The observed improvements in the experimental group can be attributed to several mechanisms. First, Swiss ball exercises provide enhanced proprioceptive input and challenge the sensorimotor system through the unstable surface, potentially facilitating neural reorganization and motor learning (Pu et al., 2023). Second, the progressive nature of the exercise program, with increasing complexity over the 8-week period, may have optimized motor learning through appropriate challenge and adaptation. Third, the integration of cognitive tasks during physical exercises may have enhanced attentional processing and cognitive-motor integration, which are often impaired in stroke patients (Andersson et al., 2024).

Our findings align with previous research suggesting that task-specific, challenging interventions that mimic real-world functional demands may yield greater improvements in functional outcomes compared to conventional approaches alone. The dual-task Swiss ball exercise program used in this study incorporated elements of both motor and cognitive challenge in a progressive manner, potentially optimizing neuroplasticity and motor learning. Furthermore, the exercises were designed to target core stability, weight shifting, and balance control, which are crucial components of effective gait and balance.

Several limitations should be acknowledged. First, the relatively small sample size limits the generalizability of our findings. Second, the follow-up period was limited to the immediate post-intervention assessment, without evaluation of long-term retention of benefits. Third, despite efforts to standardize the conventional rehabilitation program, variations in individual therapy sessions may have influenced outcomes. Fourth, the study included participants with a specific range of functional abilities (Brunnstrom stage ≥ 4), limiting generalizability to patients with more severe impairments. Future studies should address these limitations through larger sample sizes, longer follow-up periods, and inclusion of a broader range of stroke severities.

5. Conclusion

This study demonstrates that a modified dual-task Swiss ball exercise program, when added to conventional rehabilitation, leads to significantly greater improvements in balance, gait parameters, and dual-task performance in unilateral stroke patients compared to conventional



rehabilitation alone. The significant reduction in dual-task cost observed in the experimental group suggests that this intervention may enhance patients' ability to allocate attentional resources efficiently during concurrent tasks, a critical skill for functional independence in daily activities. The strong correlation between balance improvement and dual-task cost reduction highlights the interconnectedness of balance control and cognitive processing in motor performance.

These findings suggest that incorporating challenging, progressive dual-task exercises using Swiss balls into rehabilitation protocols may enhance functional outcomes for stroke patients. Future research should investigate the long-term retention of these benefits, explore the neurophysiological mechanisms underlying the observed improvements, and examine the efficacy of this approach in patients with varying stroke severities and in different stages of recovery.

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