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OPTIMISING BALANCE AND GAIT IN STROKE PATIENTS: A COMPARATIVE STUDY OF SWISS-BALL DUAL-TASK EXERCISES VS. CONVENTIONAL THERAPY

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ABSTRACT

Stroke is a leading cause of long-term disability worldwide, with balance and gait impairments being common sequelae. This study aimed to compare the effectiveness of Swiss-Ball dual-task exercises versus conventional therapy in improving balance and gait parameters in post-stroke patients. In this randomized controlled trial, 64 stroke survivors (aged 25-65 years) were allocated to either a Swiss-Ball dual-task exercise program (n=32) or conventional therapy (n=32) for 8 weeks. Outcome measures included the Berg Balance Scale (BBS), Timed Up and Go Test (TUG), 10-Meter Walk Test (10MWT), and Functional Gait Assessment (FGA). Results demonstrated that patients in the Swiss-Ball dual-task group showed significantly greater improvements in dynamic balance (mean BBS improvement 8.7±2.3 vs. 5.4±2.1, $p<0.001$) and functional mobility (mean TUG improvement 4.2±1.1 vs. 2.8±1.3 seconds, $p<0.01$) compared to the conventional therapy group. Both interventions improved gait speed, but the Swiss-Ball group demonstrated superior outcomes in dual-task gait parameters. These findings suggest that Swiss-Ball dual-task exercises may provide enhanced rehabilitation outcomes for balance and gait recovery in stroke patients compared to conventional approaches. Incorporating this innovative intervention could optimize functional recovery and potentially reduce fall risk in the stroke population.

Keywords: Stroke Rehabilitation, Swiss-Ball Exercises, Dual-Task Training, Balance, Gait

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1. INTRODUCTION

Stroke remains a significant global health challenge, ranking as a leading cause of long-term disability worldwide (Johnson et al., 2019). With advancements in acute stroke management improving survival rates, the focus on effective rehabilitation strategies has become increasingly important. Balance and gait impairments are among the most common and debilitating consequences of stroke, significantly impacting patients' functional independence, quality of life, and safety (Stefanovic Budimkic et al., 2017).

The global burden of stroke continues to increase, with projections indicating a substantial rise in stroke incidence, deaths, and disability-adjusted life years from 2020 to 2030 (Pu et al., 2023). This trend underscores the critical need for innovative, effective rehabilitation approaches that can optimize functional recovery and reduce disability following stroke.

Conventional stroke rehabilitation typically involves targeted exercises focusing on strength, flexibility, balance, and task-specific training (Pandian et al., 2018). While these approaches have demonstrated efficacy, there is growing interest in exploring novel interventions that may enhance outcomes, particularly for complex functional tasks like maintaining balance while performing concurrent cognitive or motor activities—a capability essential for community reintegration and independent living.

Swiss-Ball exercises, which utilize an unstable surface to challenge the neuromuscular system, have gained attention in rehabilitation settings. The inherent instability of the Swiss-Ball requires continuous postural adjustments, potentially enhancing proprioception, muscle activation patterns, and core stability (Lo et al., 2021). When combined with dual-task paradigms—where patients perform cognitive or secondary motor tasks simultaneously with balance activities—these exercises may better simulate real-world functional demands and potentially accelerate recovery of balance and gait functions.

Despite the theoretical benefits, limited research has directly compared the effectiveness of Swiss-Ball dual-task exercises with conventional therapy for balance and gait rehabilitation after stroke. This study aims to address this gap by conducting a randomized controlled trial comparing these two approaches, with the hypothesis that Swiss-Ball dual-task exercises will yield superior outcomes in balance and gait parameters compared to conventional therapy.

2. METHODS

2.1. STUDY DESIGN AND PARTICIPANTS

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

Participants were recruited from the outpatient stroke rehabilitation department using the following inclusion criteria: (1) first-ever ischemic or hemorrhagic stroke confirmed by neuroimaging; (2) stroke onset between 3 and 12 months prior to enrollment; (3) age between 25 and 65 years; (4) ability to stand independently for at least 1 minute; (5) ability to walk at least 10 meters with or without an assistive device; and (6) Mini-Mental State Examination score ≥24.

Exclusion criteria included: (1) severe cardiovascular conditions contraindicating exercise; (2) other neurological disorders affecting balance or gait; (3) severe visual or hearing impairments; (4) orthopedic conditions limiting participation; (5) uncontrolled hypertension (>180/100 mmHg); and (6) participation in other experimental rehabilitation studies.

2.2. SAMPLE SIZE CALCULATION AND RANDOMIZATION

Sample size was calculated based on previous studies using the Berg Balance Scale (BBS) as the primary outcome measure. Assuming a mean difference of 4 points between groups (standard deviation = 5), with 80% power and a significance level of 0.05, a minimum of 26 participants per group was required. Accounting for a potential 20% dropout rate, we aimed to recruit 32 participants per group.

Block randomization (block size of 4) was performed using a computer-generated random sequence. Allocation was concealed using sequentially numbered, opaque, sealed envelopes. An independent researcher not involved in participant assessment or intervention administration performed the randomization process.

2.3. INTERVENTIONS

Both intervention groups received 24 sessions of therapy (3 sessions per week for 8 weeks), with each session lasting 60 minutes.

1) **Swiss-Ball Dual-Task Exercise Group (SBDT)**: Participants in this group performed a progressive program of exercises on a Swiss-Ball while simultaneously engaging in cognitive or secondary motor tasks. The program included:
    1) Seated balance exercises on the Swiss-Ball with graded progression from static to dynamic sitting
    2) Reaching tasks in multiple directions while maintaining seated balance

3) Weight-shifting exercises in sitting and modified standing positions
4) Transitional movements (sit-to-stand, stand-to-sit) using the Swiss-Ball
5) Modified stepping exercises with the Swiss-Ball as support

Dual-task components were progressively integrated and included arithmetic calculations, verbal fluency tasks, object manipulation, and rhythmic movements synchronized to metronome beats. Exercise difficulty was progressed by changing the size/inflation of the ball, reducing base of support, increasing movement amplitude, and increasing dual-task complexity.

2) **Conventional Therapy Group (CT)**: Participants in this group received standard rehabilitation including:
   1) Progressive balance exercises on stable surfaces
   2) Weight-shifting and reaching activities in sitting and standing
   3) Stepping and weight transfer exercises
   4) Walking training with progressive reduction in support
   5) Functional task training

The conventional program focused on single-task training with each component practiced separately, following standard rehabilitation protocols.

Both groups received identical education on stroke risk factor management and home exercise recommendations.

3. OUTCOME MEASURES

Assessments were conducted at baseline (T0), after 4 weeks (T1), after 8 weeks of intervention (T2), and at 4-week follow-up (T3). All assessments were performed by trained physiotherapists blinded to group allocation.

3.1. PRIMARY OUTCOME MEASURES

1) **Berg Balance Scale (BBS)**: A 14-item scale assessing static and dynamic balance with scores ranging from 0-56, with higher scores indicating better balance.
2) **Timed Up and Go Test (TUG)**: Measuring the time taken to rise from a chair, walk 3 meters, turn, walk back, and sit down, with faster times indicating better functional mobility.

3.2. SECONDARY OUTCOME MEASURES

1) **10-Meter Walk Test (10MWT)**: Assessing comfortable and fast gait speeds.
2) **Functional Gait Assessment (FGA)**: A 10-item test evaluating gait performance during various challenging conditions (maximum score 30).
3) **Dual-Task Cost (DTC)**: Calculated for gait speed and TUG performance while performing a concurrent cognitive task (serial subtraction by threes), using the formula: DTC = [(single-task performance − dual-task performance)/single-task performance] × 100%.
4) **Activities-specific Balance Confidence Scale (ABC)**: A 16-item self-report measure of balance confidence during various activities (0-100%).

3.3. STATISTICAL ANALYSIS

Data analysis was performed using Python (version 3.9.0) with SciPy and Statsmodels packages. Normality of data distribution was assessed using the Shapiro-Wilk test. Baseline characteristics were compared using independent t-tests for continuous variables and chi-square tests for categorical variables.

A mixed-model ANOVA with group (SBDT vs. CT) as the between-subjects factor and time (T0, T1, T2, T3) as the within-subjects factor was used to analyze outcome measures. Post-hoc analyses with Bonferroni correction were conducted for significant interaction effects. Intention-to-treat analysis was applied using the last observation carried forward method for missing data. Effect sizes were calculated using Cohen's d. Statistical significance was set at $p<0.05$.

4. RESULTS

4.1. PARTICIPANT CHARACTERISTICS

A total of 78 patients were screened for eligibility, with 64 meeting the inclusion criteria and randomized to either the SBDT group (n=32) or CT group (n=32). Three participants in the SBDT group and four in the CT group did not complete the intervention (Figure 1). Reasons for dropout included medical complications unrelated to the intervention (n=3), transportation issues (n=2), and personal reasons (n=2). Analysis was performed on all 64 randomized participants following intention-to-treat principles.

Baseline demographic and clinical characteristics were comparable between groups (Table 1). The mean age was 52.7±9.4 years in the SBDT group and 54.3±8.9 years in the CT group. The majority of participants had ischemic stroke (78.1% in SBDT, 75.0% in CT), with a mean time since stroke of 6.4±2.7 months in the SBDT group and 6.8±2.5 months in the CT group.

Table 1 Baseline Demographic and Clinical Characteristics of Participants

Characteristic	SBDT Group (n=32)	CT Group (n=32)	p-value
Age (years), mean±SD	52.7±9.4	54.3±8.9	0.483
Gender, n (%)			0.617
Male	19 (59.4)	17 (53.1)	
Female	13 (40.6)	15 (46.9)	
Time since stroke (months), mean±SD	6.4±2.7	6.8±2.5	0.547
Type of stroke, n (%)			0.771
Ischemic	25 (78.1)	24 (75.0)	
Hemorrhagic	7 (21.9)	8 (25.0)	
Affected side, n (%)			0.802
Right	17 (53.1)	16 (50.0)	
Left	15 (46.9)	16 (50.0)	
Assistive device use, n (%)			0.614
None	12 (37.5)	10 (31.3)	
Single-point cane	15 (46.9)	18 (56.3)	
Quad cane/walker	5 (15.6)	4 (12.5)	
Hypertension, n (%)	22 (68.8)	24 (75.0)	0.584
Diabetes mellitus, n (%)	13 (40.6)	11 (34.4)	0.609
MMSE score, mean±SD	27.3±2.1	26.9±2.3	0.465

SBDT: Swiss-Ball Dual-Task; CT: Conventional Therapy; SD: Standard Deviation; MMSE: Mini-Mental State Examination

4.2. PRIMARY OUTCOMES

Both groups showed significant improvements in BBS and TUG scores across all time points compared to baseline ($p<0.001$). However, the SBDT group demonstrated significantly greater improvements in both measures compared to the CT group (Table 2).

For the BBS, a significant group × time interaction was observed ($F(3,186)=12.74$, $p<0.001$). Post-hoc analyses revealed that while both groups improved, the SBDT group showed significantly greater improvements at T1 (mean difference=2.1, $p=0.024$), T2 (mean difference=3.3, $p<0.001$), and T3 (mean difference=3.6, $p<0.001$).

Similarly, for the TUG test, a significant group × time interaction was found ($F(3,186)=9.37$, $p<0.001$). The SBDT group demonstrated significantly greater reductions in TUG time at T2 (mean difference=1.4s, $p=0.007$) and T3 (mean difference=1.7s, $p=0.003$) compared to the CT group.

Table 2 Changes in Primary Outcome Measures Across Time Points

Outcome Measure	Group	Baseline (T0)	4 Weeks (T1)	8 Weeks (T2)	Follow-up (T3)	Within-Group p-value	Between-Group p-value (T2-T0)
BBS (0-56)	SBDT	36.9±5.3	41.8±5.1	45.6±4.7	46.2±4.5	<0.001	<0.001
	CT	37.2±5.5	40.1±5.3	42.6±5.4	43.0±5.6	<0.001	
TUG (seconds)	SBDT	19.6±4.5	17.2±4.1	15.4±3.8	15.1±3.7	<0.001	0.007
	CT	19.3±4.3	17.8±4.2	16.5±4.0	16.4±4.1	<0.001	

BBS: Berg Balance Scale; TUG: Timed Up and Go Test; SBDT: Swiss-Ball Dual-Task; CT: Conventional Therapy

4.3. SECONDARY OUTCOMES

Both interventions improved gait speed and functional gait performance, but the SBDT group demonstrated superior outcomes in dual-task conditions and gait parameters (Table 3).

The SBDT group showed significantly greater improvements in the FGA (mean difference=2.7, p=0.003) compared to the CT group. While both groups improved in comfortable and fast gait speeds, differences between groups were not statistically significant for single-task walking (p=0.128 for comfortable speed, p=0.097 for fast speed).

However, the SBDT group demonstrated significantly smaller dual-task costs for both gait speed (mean difference=8.3%, p<0.001) and TUG performance (mean difference=7.9%, p<0.001) compared to the CT group, indicating better ability to maintain performance during dual-task conditions.

Self-reported balance confidence (ABC scale) improved significantly more in the SBDT group compared to the CT group (mean difference=9.7%, p=0.002).

Table 3 Changes in Secondary Outcome Measures from Baseline to 8 Weeks

Outcome Measure	SBDT Group (n=32)			CT Group (n=32)			Between-Group p-value
	Baseline	8 Weeks	Change	Baseline	8 Weeks	Change	
10MWT (m/s)							
Comfortable speed	0.58±0.15	0.74±0.16	0.16±0.07	0.57±0.14	0.70±0.15	0.13±0.08	0.128
Fast speed	0.76±0.19	0.96±0.21	0.20±0.09	0.75±0.18	0.91±0.20	0.16±0.10	0.097
FGA (0-30)	15.3±3.9	21.6±4.1	6.3±2.4	15.1±4.0	18.7±4.3	3.6±2.2	0.003
Dual-Task Cost (%)							
Gait speed	26.5±7.2	15.3±5.8	-11.2±3.9	27.1±7.4	24.2±6.8	-2.9±3.1	<0.001
TUG	29.7±8.1	18.2±6.4	-11.5±4.3	28.9±7.9	25.3±7.1	-3.6±3.5	<0.001
ABC Scale (%)	57.3±11.8	76.5±12.7	19.2±7.6	58.1±12.2	67.6±13.4	9.5±6.9	0.002

10MWT: 10-Meter Walk Test; FGA: Functional Gait Assessment; ABC: Activities-specific Balance Confidence Scale; SBDT: Swiss-Ball Dual-Task; CT: Conventional Therapy

4.4. VISUALIZATION OF RESULTS

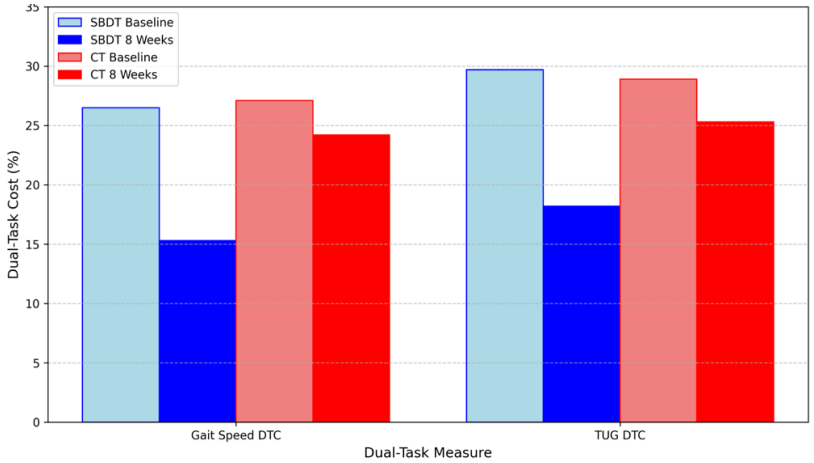

Figure 1 Changes in Dual- Task Cost from Baseline to 8 Weeks

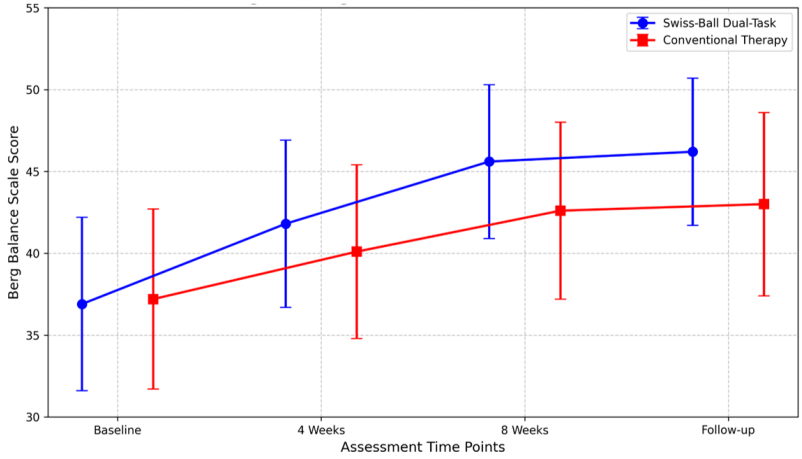

Figure 2 Changes in Berg Balance Scale Scores Over Time

5. DISCUSSION

This study compared the effectiveness of Swiss-Ball dual-task exercises with conventional therapy for improving balance and gait in individuals recovering from stroke. Our findings demonstrate that both interventions led to significant improvements in balance, functional mobility, and gait parameters, but the Swiss-Ball dual-task approach yielded superior outcomes across most measures, particularly for dynamic balance, dual-task performance, and balance confidence.

The greater improvement in BBS scores in the SBDT group aligns with the theoretical framework that unstable surface training provides enhanced proprioceptive input and challenges the neuromuscular system to a greater extent than stable surface training (Chan et al., 2021). The Swiss-Ball creates an unstable base that requires continuous postural adjustments, potentially enhancing sensorimotor integration and core muscle activation—key components for balance control. The observed between-group difference of 3.3 points on the BBS exceeds the minimal clinically important difference of 2.5 points reported for stroke patients (Guzik & Bushnell, 2017), suggesting clinically meaningful improvements.

The significantly greater reduction in dual-task costs in the SBDT group represents a particularly important finding, as dual-task capability is crucial for community ambulation and daily functioning. By simultaneously practicing balance tasks and cognitive activities during training, the SBDT group likely developed more automated motor control strategies, allowing for more attentional resources to be allocated to secondary tasks—a critical skill for real-world functioning (Lo

et al., 2021). This improvement in dual-task performance may translate to enhanced safety and independence in community environments where multiple demands on attention are common.

The superior improvement in self-reported balance confidence (ABC scale) in the SBDT group is noteworthy, as psychological factors significantly impact functional recovery and activity participation after stroke (Aycock et al., 2023). The progressive mastery of increasingly challenging balance tasks on an unstable surface may have enhanced participants' self-efficacy for balance activities, potentially contributing to greater participation in daily activities and reduced fear of falling.

Interestingly, while the SBDT group showed greater improvements in functional gait measures (FGA) and dual-task gait performance, differences in single-task gait speed were not statistically significant between groups. This suggests that conventional therapy is equally effective for improving basic walking speed, but Swiss-Ball dual-task training may provide additional benefits for more complex gait tasks that require dynamic balance control and dual-task capability.

Our findings align with previous research demonstrating the effectiveness of dual-task training for improving balance and mobility in neurological populations (Boot et al., 2020). However, our study extends this work by specifically examining the added value of combining dual-task paradigms with unstable surface training using a Swiss-Ball, which appears to enhance outcomes beyond either approach alone.

Several mechanisms may explain the superior effects of the SBDT approach. First, the inherent instability of the Swiss-Ball likely provides enhanced proprioceptive input, challenging the sensorimotor system to a greater extent than stable surfaces. Second, the dual-task component may promote neural plasticity through simultaneous activation of motor and cognitive networks. Third, the progressive nature of the SBDT program, with systematic increases in both balance challenges and cognitive demands, may provide optimal loading for neuromuscular adaptation while maintaining engagement and motivation.

6. LIMITATIONS

Despite promising results, several limitations should be acknowledged. First, the relatively short follow-up period (4 weeks post-intervention) limits conclusions about long-term retention of improvements. Second, while assessors were blinded, participants and therapists could not be blinded to group allocation due to the nature of the interventions. Third, the study included participants with moderate motor impairments who could stand independently, limiting generalizability to the broader stroke population. Finally, detailed neuroimaging assessments were not conducted, precluding analysis of potential neuroplastic mechanisms underlying observed improvements.

7. CONCLUSION

This randomized controlled trial demonstrates that a Swiss-Ball dual-task exercise program yields superior improvements in balance, functional mobility, dual-task performance, and balance confidence compared to conventional therapy in individuals recovering from stroke. The SBDT approach appears particularly beneficial for enhancing dynamic balance control and dual-task capability—skills essential for safe and independent functioning in complex real-world environments.

These findings suggest that incorporating Swiss-Ball exercises with progressive dual-task challenges into stroke rehabilitation programs may optimize functional recovery and potentially reduce fall risk. Future research should investigate the long-term effects of this approach, examine potential neuroplastic mechanisms using advanced neuroimaging, and assess the cost-effectiveness and feasibility of implementing this intervention in various rehabilitation settings.

CONFLICT OF INTERESTS

None.

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