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WALK BETTER, LIVE BETTER: EFFECTS OF DUAL-TASK GAIT TRAINING ON BALANCE AND FUNCTIONAL MOBILITY AFTER STROKE – A RANDOMIZED CONTROLLED TRIAL

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Abstract

Background

Stroke frequently results in persistent impairments in balance, gait, and functional mobility. Conventional rehabilitation primarily emphasizes single-task walking and functional exercises, whereas everyday walking commonly requires individuals to simultaneously manage cognitive and motor demands. Dual-task gait training may therefore provide an additional rehabilitation stimulus by integrating cognitive or motor challenges with walking practice. This study investigated the effects of structured dual-task gait training on balance and functional mobility following stroke compared with conventional rehabilitation.

Methods

A two-arm, parallel-group randomized controlled trial was conducted among 48 individuals following stroke, who were randomly allocated to a dual-task gait training group (DTG, n = 24) or conventional rehabilitation group (CRG, n = 24). Both groups received a structured four-week rehabilitation program consisting of 12 sessions. DTG received progressive dual-task gait training incorporating cognitive and motor challenges, whereas the CRG received conventional single-task rehabilitation. The primary outcomes were balance assessed using the Berg Balance Scale (BBS) and functional mobility assessed using the Timed Up and Go (TUG) test. Secondary

outcomes included 10-Meter Walk Test (10MWT) walking speed, dual-task walking speed, and dual-task interference. Outcomes were assessed at baseline immediately after the intervention. The principal treatment effect was evaluated using the group × time interaction.

Results

Both groups demonstrated significant improvements following the intervention; however, the magnitude of improvement was greater in the DTG. BBS scores increased from 39.58 ± 5.26 to 48.63 ± 4.21 in the DTG compared with 39.71 ± 5.41 to 44.36 ± 4.69 in the CRG (group × time, $p < 0.001$). TUG completion time decreased from 19.72 ± 3.69 to 14.18 ± 2.76 seconds in the DTG and from 19.83 ± 3.91 to 16.92 ± 3.16 seconds in the CRG ($p < 0.001$). Walking speed increased from 0.60 ± 0.14 to 0.83 ± 0.16 m/s in the DTG and from 0.61 ± 0.13 to 0.73 ± 0.15 m/s in the CRG ($p = 0.001$). Dual-task walking speed increased from 0.42 ± 0.12 to 0.70 ± 0.14 m/s in the DTG compared with 0.43 ± 0.11 to 0.56 ± 0.13 m/s in the CRG ($p < 0.001$). Dual-task interference decreased from 29.8 ± 8.0% to 15.2 ± 6.1% in the DTG and from 30.4 ± 7.6% to 22.8 ± 6.9% in the CRG ($p < 0.001$). Treatment adherence was high in both groups, and no serious intervention-related adverse events were reported.

Conclusion

Structured dual-task gait training produced greater improvements in balance, functional mobility, walking speed, dual-task walking performance, and dual-task interference than conventional rehabilitation alone. The findings suggest that progressively integrating cognitive-motor challenges into gait practice may provide additional functional benefits for individuals following stroke, particularly in maintaining walking performance under divided-attention conditions. Larger trials with longer follow-up are warranted to determine the durability and broader functional impact of these improvements.

INTRODUCTION

Stroke is one of the leading causes of long-term neurological disability and commonly results in persistent impairments in motor control, balance, gait, and functional mobility (1). Although many stroke survivors regain the ability to walk independently, their walking performance may remain characterized by reduced speed, altered spatial-temporal parameters, asymmetry, impaired postural control, and increased susceptibility to instability, particularly when environmental or cognitive demands are introduced (2). These limitations can substantially restrict community ambulation and participation in daily activities (3, 4). Therefore, contemporary stroke rehabilitation increasingly emphasizes not only the restoration of basic walking ability but also the development of safe and efficient walking under the complex conditions encountered in everyday life.

Conventional gait rehabilitation generally involves repetitive walking practice, balance activities, strengthening exercises, and task-specific mobility training. Although these approaches can improve walking capacity, real-world walking rarely occurs as an isolated activity. Stroke survivors commonly walk while talking, carrying objects, monitoring their surroundings, negotiating obstacles, or performing another cognitive task. Consequently, the ability to maintain safe and efficient gait while simultaneously performing a secondary task represents an important component of functional mobility (2). This has led to increasing interest in dual-task training, in which walking or another motor activity is performed simultaneously with a cognitive or secondary motor task.

The relevance of dual-task training is supported by evidence demonstrating that stroke survivors experience considerable interference when walking is combined with another task. A systematic review and meta-analysis reported that the magnitude and pattern of dual-task interference after stroke vary according to the type of secondary task and the specific gait parameter being examined (5). This finding suggests that walking performance under dual-task conditions may reveal deficits that are not readily apparent during conventional single-task gait assessment. Thus, rehabilitation strategies that deliberately expose patients to simultaneous motor and cognitive demands may have greater ecological relevance than interventions based exclusively on isolated walking practice.

Early clinical evidence has demonstrated promising effects of dual-task-specific rehabilitation. Iqbal et al. reported that dual-task-specific training produced improvements in several gait outcomes among individuals with hemiplegic stroke, supporting the use of simultaneous task practice as an approach to improve ambulation (6). Similarly, a randomized controlled trial by Baek et al. demonstrated that treadmill-based dual-task gait training improved gait parameters under dual-task conditions and reduced dual-task interference compared with training in which gait and cognitive tasks were practiced separately (7). Importantly, improvements were observed not only in gait speed but also in stride and gait variability, indicating that dual-task training may improve the quality and stability of walking when attentional demands are increased.

The potential benefits of dual-task rehabilitation have also been supported by systematic reviews and meta-analyses. Zhou et al. analyzed 13 randomized controlled trials involving 326 participants and reported that cognitive-motor dual-task training significantly improved walking balance and gait ability in people with stroke (8). These findings suggest that combining cognitive and motor demands during rehabilitation may provide benefits beyond conventional single-task approaches. However, the authors also highlighted variability between interventions and outcomes, indicating that the effectiveness of dual-task training may depend on the specific training protocol and patient characteristics (8).

Further evidence was provided by Zhang et al., who analyzed 15 randomized controlled trials involving 512 individuals with stroke. Their meta-analysis demonstrated that dual-task training produced significantly greater improvements in step length, cadence, and Berg Balance Scale scores compared with conventional rehabilitation (9). However, significant differences were not observed for gait speed or the Timed Up and Go (TUG) test (9). These findings are clinically important because they suggest that dual-task training may not affect all aspects of mobility equally. Improvements may be more evident in balance and spatial-temporal gait characteristics than in global measures of functional mobility.

Another systematic review specifically examined dual-task interference during walking following stroke and demonstrated that the effect of a secondary task on gait depends substantially on the cognitive or motor task being performed (5). This supports the concept that dual-task training should not be viewed as a single standardized intervention; rather, the nature, complexity, and progression of the secondary task may influence the resulting rehabilitation response. A structured progression from relatively simple cognitive or motor tasks toward more demanding activities may therefore be necessary to challenge attentional allocation and postural control appropriately.

Evidence from subsequent research has continued to support the integration of dual-task activities into stroke rehabilitation. A randomized controlled trial examining repeated walking practice combined with a secondary task reported beneficial effects on walking and balance functions in individuals with subacute stroke (10). Such findings are consistent with the principle of task-specific training, whereby patients repeatedly practice the functional activity under conditions that resemble the demands of everyday life. Importantly, incorporating a secondary task during walking may encourage patients to develop strategies for maintaining gait while simultaneously processing additional information.

The potential role of dual-task training in improving balance has received particular attention. A systematic review and network meta-analysis of balance and gait interventions reported beneficial effects of dual-task approaches on specific balance outcomes in stroke survivors, although the certainty of evidence varied across outcomes (11). Balance is particularly important because post-stroke walking requires continuous control of the body's center of mass while responding to internal and external demands. When attention is divided between walking and another task, the ability to maintain postural

stability may be challenged further. Consequently, training under dual-task conditions may provide an opportunity to improve the automaticity and adaptability of postural control.

Research has also investigated more comprehensive dual-task interventions incorporating trunk and postural control exercises. An RCT examining intensive multiplanar trunk training combined with dual-task exercises demonstrated improvements in balance, mobility, and fall-related outcomes following stroke (12). These findings suggest that dual-task rehabilitation may be particularly valuable when integrated with interventions addressing proximal stability and whole-body movement control. Because effective gait requires coordinated control of the trunk, pelvis, lower limbs, and attentional resources, interventions that address these components simultaneously may have functional relevance.

The effects of dual-task training have also been examined in relation to walking endurance. Jung et al. investigated the incorporation of a dual-task condition into repeated six-minute walking practice in individuals with subacute stroke and reported beneficial effects on walking and balance-related functions (10). This is clinically meaningful because community ambulation often requires individuals to sustain walking while simultaneously attending to environmental information, conversations, navigation, or other activities. Therefore, incorporating secondary tasks into endurance-oriented gait practice may provide a more realistic rehabilitation challenge than uninterrupted walking alone.

Despite encouraging findings, not all trials have demonstrated superiority of dual-task training over single-task gait training. Plummer et al. conducted a randomized controlled trial comparing cognitive-motor dual-task gait training with single-task gait training and found improvements in gait speed but did not demonstrate a significant treatment effect on the relative magnitude of dual-task interference (13). The authors suggested that individuals with greater baseline dual-task interference may potentially derive greater benefit from dual-task-specific training (13). This observation is important because improvement in absolute walking speed does not necessarily indicate improved ability to divide attention between walking and another task. Consequently, both conventional gait outcomes and dual-task-specific outcomes should be considered when evaluating the effectiveness of this rehabilitation approach.

More recent evidence has further examined the effect of different forms of dual-task training. Chuang et al. investigated multimodal training with dual-task activities and reported improvements in dual-task gait-speed performance that were maintained at follow-up (14). Their findings suggest that appropriately designed multimodal dual-task interventions may improve the ability to maintain walking performance when cognitive and motor demands occur simultaneously. Importantly, the observed improvement was not simply attributable to sacrificing cognitive performance to preserve gait, suggesting a potential improvement in the ability to manage concurrent task demands (14).

The evidence was further synthesized by Zhang et al. in a 2024 meta-analysis and trial sequential analysis involving 17 randomized clinical trials and 751 participants. Cognitive-motor dual-task training produced a significant improvement in Berg Balance Scale scores compared with conventional rehabilitation; however, significant effects were not demonstrated for the TUG test or single-task walking speed (15). The authors graded the certainty of evidence as low and emphasized that larger and methodologically stronger trials are required (15). These findings are particularly relevant to the present study because they demonstrate that the effects of dual-task training may be more apparent in balance than in conventional single-task measures of walking.

Recent evidence from 2025 has also explored whether the type of secondary task influences rehabilitation outcomes. Hu et al. compared cognitive dual-task gait training with motor dual-task gait training in subacute stroke patients. After four weeks of intervention, both groups demonstrated improvements in lower-limb coordination during walking, with no significant difference between the two training approaches (16). These results indicate that both cognitive and motor secondary tasks may provide sufficient challenge to stimulate improvements in walking coordination, although the optimal selection of secondary tasks may depend on the individual's specific rehabilitation needs (16).

A larger 2025 systematic review and meta-analysis by Mou et al. synthesized 30 randomized controlled trials involving 1,588 participants. The authors reported that dual-task training improved walking performance, lower-limb motor function, cognitive function, mental status, and activities of daily living compared with control interventions (17). Subgroup analyses further suggested that interventions lasting at least three weeks were more likely to demonstrate clinically meaningful effects (17). This relatively large

evidence base strengthens the rationale for incorporating dual-task activities into stroke rehabilitation while simultaneously highlighting the importance of adequate intervention duration and appropriate training progression.

Collectively, the literature indicates that dual-task gait training has the potential to improve balance, spatial-temporal gait characteristics, walking performance, and the ability to manage simultaneous cognitive or motor demands following stroke (17). Nevertheless, important gaps remain. Existing studies differ considerably in stroke chronicity, intervention duration, type of secondary task, training intensity, outcome measures, and comparison interventions. Moreover, some studies demonstrate improvements in gait parameters without corresponding reductions in dual-task interference, while meta-analyses have reported inconsistent effects on measures such as gait speed and the TUG test (15). These inconsistencies indicate that further well-designed randomized controlled trials are needed to clarify the clinical effectiveness of structured dual-task gait training, particularly when the primary outcomes are balance and functional mobility.

Therefore, the present study, "Walk Better, Live Better: Effects of Dual-Task Gait Training on Balance and Functional Mobility After Stroke, A Randomized Controlled Trial," is designed to investigate whether a structured dual-task gait training program can produce greater improvements in balance and functional mobility than conventional rehabilitation. By combining gait practice with simultaneous cognitive or motor challenges, the intervention aims to reproduce the attentional and motor demands encountered during everyday walking. Evaluating balance and functional mobility may provide clinically meaningful evidence regarding whether dual-task gait training can translate into improved functional performance rather than merely improving isolated gait parameters.

2. OBJECTIVE

The primary objective of this randomized controlled trial is to determine the effects of dual-task gait training on balance and functional mobility in individuals following stroke compared with conventional gait rehabilitation.

Specific Objectives

1. To determine the effect of dual-task gait training on balance in individuals following stroke.
2. To determine the effect of dual-task gait training on functional mobility in individuals following stroke.
3. To compare changes in balance between individuals receiving dual-task gait training and conventional rehabilitation.
4. To compare changes in functional mobility between individuals receiving dual-task gait training and conventional rehabilitation.
5. To determine whether dual-task gait training provides additional functional benefits beyond conventional rehabilitation in post-stroke individuals.

3. METHODOLOGY

3.1 Study Design

A two-arm, parallel-group randomized controlled trial (RCT) was conducted to determine the effects of dual-task gait training on balance and functional mobility in individuals following stroke. The study compared a structured dual-task gait training program with conventional physiotherapy rehabilitation. The primary outcomes were balance and functional mobility, while walking speed and dual-task walking performance were assessed as secondary outcomes. The study was designed and reported in accordance with the principles of the Declaration of Helsinki and the Consolidated Standards of Reporting Trials (CONSORT) guidelines.

3.2 Study Setting and Duration

The study was conducted in the physiotherapy and rehabilitation department of the selected clinical setting. Participants were recruited from patients receiving outpatient physiotherapy services. The study was conducted over a period that included participant recruitment, baseline assessment, intervention,

post-intervention assessment, and statistical analysis. All participants completed a structured four-week rehabilitation program.

3.3 Study Population

The study population consisted of adult individuals with a confirmed diagnosis of stroke who had residual impairments in balance and functional mobility. Participants were selected because they had sufficient walking ability to participate in gait training but continued to experience functional limitations that could affect safe and efficient mobility. This population was considered appropriate for evaluating whether the addition of cognitive and motor challenges during walking could provide additional benefits over conventional rehabilitation.

3.4 Sample Size

A total of 48 participants were included in the study and randomly allocated into two equal groups. Group A comprised 24 participants who received dual-task gait training, while Group B comprised 24 participants who underwent conventional rehabilitation. The sample size was selected to ensure a balanced comparison between the intervention and control groups while maintaining feasibility within the study setting.

3.5 Sampling Technique

Participants were recruited using a non-probability consecutive sampling technique. Individuals presenting to the rehabilitation department were screened according to the predefined eligibility criteria. Eligible participants who agreed to participate were enrolled until the required sample of 48 participants was achieved. Following baseline assessment, participants were randomly assigned to either the dual-task gait training group or the conventional rehabilitation group.

3.6 Eligibility Criteria

3.6.1 Inclusion Criteria

Participants were included if they fulfilled the following criteria:

- Adults aged 18 years or older.
- Had a clinically confirmed diagnosis of stroke.
- Were in the subacute or chronic stage following stroke.
- Were medically stable and able to participate in physiotherapy.
- Were able to stand independently.
- Were able to walk independently or with minimal assistance.
- Were able to follow simple verbal instructions.
- Had sufficient cognitive and communication ability to perform the prescribed dual-task activities.
- Were able to complete the baseline functional assessments.
- Provided written informed consent to participate in the study.
-

3.6.2 Exclusion Criteria

Participants were excluded if they had:

- A history of recurrent or bilateral stroke that substantially affected mobility assessment.
- Another neurological condition affecting gait or balance.
- Severe musculoskeletal disorders affect walking.
- Severe visual or auditory impairment that prevented participation.
- Severe cognitive impairment prevents comprehension of the intervention.
- Uncontrolled cardiovascular or other medical conditions contraindicating exercise.
- Severe vestibular dysfunction affects balance.
- Acute pain that substantially restricted walking.
- Participation in another structured experimental rehabilitation program during the study period.
- Any medical condition that made dual-task gait training unsafe.

3.7 Recruitment Procedure

Potential participants were identified from the physiotherapy and rehabilitation services of the study setting. Each potential participant was initially screened against the inclusion and exclusion criteria. Those who met the eligibility requirements were provided with detailed information about the purpose and procedures of the study. The participants were informed about the expected duration of treatment, assessment procedures, potential benefits, and possible risks associated with participation. Written informed consent was obtained before enrollment. Participants were informed that participation was voluntary and that they could withdraw from the study at any stage without affecting their routine clinical care.

3.8 Randomization

After completion of the baseline assessment, the 48 participants were randomly allocated into two groups. A computer-generated randomization sequence was used to allocate participants in a 1:1 ratio. Twenty-four participants were allocated to the dual-task gait training group, while 24 participants were allocated to the conventional rehabilitation group. Allocation was performed using sequentially numbered, opaque, sealed envelopes. The envelopes were prepared before participant allocation and were opened after completion of the baseline assessment. This procedure was used to minimize selection bias and maintain appropriate allocation concealment.

3.9 Blinding

Due to the nature of the physiotherapy interventions, participants and treating physiotherapists could not be blinded to group allocation. However, the outcome assessor was blinded to the participants' group allocation whenever possible. Participants were instructed not to disclose their treatment allocation during the assessment. The statistical analysis was conducted using coded group identifiers to minimize potential analytical bias.

3.10 Baseline Assessment

Before commencement of the intervention, demographic and clinical characteristics of all participants were recorded. The collected information included age, sex, type of stroke, side of involvement, time since stroke, use of an assistive device, relevant medical history, and previous rehabilitation history. Following the demographic assessment, participants underwent standardized functional assessments to establish baseline performance. The baseline assessment included the Berg Balance Scale (BBS), Timed Up and Go (TUG) test, 10-Meter Walk Test (10MWT), and a dual-task walking assessment. All assessments were conducted using standardized procedures and were subsequently repeated after completion of the intervention to evaluate changes in functional performance.

3.11 Outcome Measures

3.11.1 Primary Outcome Measures

The primary outcomes of the study were balance and functional mobility.

Berg Balance Scale

The Berg Balance Scale (BBS) was used to assess functional balance. The BBS consisted of 14 functional tasks involving sitting, standing, transferring, reaching, turning, and maintaining different postures. Each item was scored from 0 to 4 according to the participant's ability to perform the task. The total score ranged from 0 to 56, with higher scores indicating better balance of performance. The BBS was selected as a primary outcome because balance was a central component of the study objective and because the scale assessed balance during functional activities relevant to post-stroke mobility.

Timed Up and Go Test

The Timed Up and Go (TUG) test was used to assess functional mobility. Participants were instructed to sit in a standard chair, stand up, walk a predetermined distance, turn around, return to the chair, and sit

down again. The time required to complete the task was recorded in seconds using a stopwatch. A shorter completion time indicated better functional mobility. The TUG was selected because it incorporated several clinically important components of mobility, including transitional movement, walking, turning, and sitting.

3.11.2 Secondary Outcome Measures

10-Meter Walk Test

Walking speed was assessed using the 10-Meter Walk Test (10MWT). Participants were instructed to walk at their comfortable self-selected walking speed along a measured walkway. Adequate acceleration and deceleration distances were provided to minimize the effect of starting and stopping. The time required to complete the measured distance was recorded, and walking speed was calculated in meters per second. Higher walking speed indicated better walking performance.

Dual-Task Walking Performance

Dual-task walking performance was also assessed to determine whether participants could maintain walking performance while simultaneously completing a secondary task. Participants were instructed to walk while performing a standardized cognitive task. The same task was used during the baseline and post-intervention assessments. The dual-task assessment was particularly relevant to the study because the intervention specifically targeted the ability to walk while managing an additional cognitive demand.

3.12 Intervention Protocol

Both groups participated in a structured four-week rehabilitation program, consisting of three treatment sessions per week, for a total of 12 sessions per participant. Each treatment session lasted approximately 45–60 minutes and followed a standardized structure comprising warm-up, balance training, gait training, and cool-down activities. The duration and frequency of treatment were kept comparable between the two groups to ensure similar rehabilitation exposure. The primary difference between the groups was the incorporation of progressive dual-task gait training in the experimental group, whereas the control group received conventional single-task rehabilitation. The detailed intervention protocols for both groups, including the weekly progression, type of exercises, secondary tasks, and duration of each treatment component, are presented in Table 1.

Table 1. Interventional protocol for the dual-task gait training group and conventional rehabilitation group

Week	Session Structure	Dual-Task Gait Training Group (n=24)	Conventional Rehabilitation Group (n=24)	Duration
Week 1	Warm-up	Active range-of-motion exercises of the lower limbs, gentle marching, weight shifting, and preparation for walking	Same warm-up activities	5–10 min
	Balance training	Static and dynamic balance activities, weight shifting, reaching, and controlled stepping	Static and dynamic balance activities, weight shifting, reaching, and controlled stepping	10 min
	Gait training	Single-task walking followed by walking while performing simple cognitive tasks, including counting forward, naming objects, and	Single-task gait training at comfortable speed, including forward walking, turning, and controlled stopping	20–25 min

		answering simple questions		
	Cool-down	Gentle walking and lower-limb stretching	Gentle walking and lower-limb stretching	5 min
Week 2	Warm-up	Lower-limb mobility exercises and walking preparation	Lower-limb mobility exercises and walking preparation	5–10 min
	Balance training	Dynamic balance with multidirectional stepping and controlled weight transfer	Dynamic balance with multidirectional stepping and controlled weight transfer	10 min
	Gait training	Walking while performing moderate cognitive tasks, including counting backward, category naming, word generation, and responding to verbal commands	Progressive single-task walking, changes in walking direction, step training, and functional walking	20–25 min
	Cool-down	Low-intensity walking and stretching	Low-intensity walking and stretching	5 min
Week 3	Warm-up	Lower-limb mobility and gait preparation	Lower-limb mobility and gait preparation	5–10 min
	Balance training	Dynamic balance with stepping, turning, obstacle negotiation, and changes in direction	Dynamic balance, stepping, turning, and obstacle negotiation performed without a secondary task	10 min
	Gait training	Advanced cognitive-motor dual-task walking, including serial subtraction, answering questions, carrying objects, changing direction, and responding to auditory commands while walking	Progressive single-task gait training, carrying objects during walking, turning, obstacle negotiation, and variable walking distances	20–25 min
	Cool-down	Low-intensity walking and stretching	Low-intensity walking and stretching	5 min
Week 4	Warm-up	Lower-limb mobility and gait preparation	Lower-limb mobility and gait preparation	5–10 min
	Balance training	Challenging dynamic balance activities with multidirectional stepping and functional reaching	Advanced dynamic balance and functional stepping activities	10 min
	Gait training	Functional and complex dual-task gait training, including walking while performing mental calculations, carrying	Advanced single-task functional gait training, including variable walking speed, obstacle negotiation, turning,	20–25 min

		objects, negotiating obstacles, changing speed/direction, stopping and restarting on command, and combining cognitive and motor tasks	carrying objects, and stair/step practice where appropriate	
	Cool-down	Gentle walking and stretching	Gentle walking and stretching	5 min

3.15 Progression of Intervention

The intervention was progressively modified according to each participant's individual performance and tolerance. Progression was achieved by gradually increasing walking distance and speed, enhancing cognitive and motor task complexity, introducing changes in walking direction, adding obstacles, reducing therapist assistance, combining cognitive and motor tasks, and increasing environmental demands. The level of difficulty was adjusted throughout the intervention to ensure an appropriate and individualized challenge. If a participant demonstrated excessive gait deterioration, loss of balance, or difficulty completing the secondary task safely, the task complexity was reduced accordingly. Participants were permitted to use their usual walking aids whenever required to ensure safety and facilitate functional mobility during training.

3.16 Safety Procedures

Safety was maintained throughout all treatment sessions, with participants closely monitored for excessive fatigue, dizziness, shortness of breath, pain, loss of balance, unsafe gait patterns, and signs of cardiovascular distress. The therapist remained near the participant during challenging gait activities and provided appropriate assistance whenever required. The intervention was modified or discontinued if a participant developed any symptoms or signs that could compromise safety. Any adverse event occurring during the intervention period was documented and appropriately managed according to the study safety procedures.

3.17 Post-Intervention Assessment

Following completion of the 12 treatment sessions, all participants underwent a post-intervention assessment. The same outcome measures used during the baseline assessment were repeated, including the Berg Balance Scale (BBS), Timed Up and Go (TUG) test, 10-Meter Walk Test (10MWT), and dual-task walking assessment. The post-intervention assessment was conducted using the same standardized procedures, instructions, and testing conditions applied during the baseline assessment to ensure consistency and comparability of the results. Whenever possible, the assessor remained blinded to the participants' group allocation to minimize potential measurement bias.

3.18 Primary and Secondary Outcomes

The primary outcomes were:

1. Change in Berg Balance Scale score from baseline to post-intervention.
2. Change in Timed Up and Go completion time from baseline to post-intervention.

The secondary outcomes were:

1. Change in 10-Meter Walk Test walking speed.
2. Change in dual-task walking performance.
3. Change in functional gait performance following the intervention.

The principal treatment effect was determined by comparing the magnitude of change between the dual-task gait training and conventional rehabilitation groups.

3.19 Data Management

Each participant was assigned a unique identification code. Personal identifying information was kept separately from the research dataset. All assessment data were recorded on standardized data collection forms and subsequently entered a computerized database. The dataset was checked for missing values, data-entry errors, and inconsistencies before statistical analysis. Participant confidentiality was maintained throughout the study.

3.20 Statistical Analysis

Statistical analysis was performed using IBM SPSS 25 Version. Descriptive statistics were used to summarize demographic and clinical characteristics. Continuous variables were expressed as mean ± standard deviation, while categorical variables were summarized using frequencies and percentages. The normality of continuous data was assessed using the Shapiro–Wilk test and visual examination of the data distribution. Baseline characteristics were compared between the two groups to assess the comparability of the groups before intervention. For the primary outcomes, changes in BBS and TUG scores from baseline to post-intervention were analyzed using an appropriate repeated-measures analytical model. The analysis examined:

- Group effect
- Time effect
- Group × time interaction

The group × time interaction was considered the principal statistical effect because it determined whether changes in balance and functional mobility differed between the dual-task and conventional rehabilitation groups. Secondary outcomes, including 10MWT and dual-task walking performance, were analyzed using the same general analytical framework. Where appropriate, effect sizes and 95% confidence intervals were calculated to describe the magnitude and precision of treatment effects. The level of statistical significance was set at $p < 0.05$.

3.21 Ethical Considerations

Ethical approval was obtained from the relevant institutional ethical review committee before commencement of the study. All participants received detailed verbal and written information regarding the study. Written informed consent was obtained from all participants before enrollment. Participants were informed that participation was voluntary and that they could withdraw from the study at any time without affecting their ongoing medical or physiotherapy care. Confidentiality and anonymity were maintained throughout the research process. Participant information was used exclusively for research purposes. All procedures were conducted according to accepted ethical principles for research involving human participants.

4. RESULTS

4.1 Participant Recruitment and Flow

A total of 64 individuals with strokes were screened for eligibility. Of these, 48 participants fulfilled the inclusion criteria and were enrolled in the study. Sixteen individuals were excluded because they did not meet the eligibility criteria or declined participation. The 48 eligible participants were randomly allocated into two groups: 24 participants to the dual-task gait training group (DTG) and 24 participants to the conventional rehabilitation group (CRG). All 48 participants completed the intervention and post-intervention assessment, resulting in a 100% retention rate. The DTG received a structured four-week dual-task gait training program in addition to conventional rehabilitation, whereas the CRG received conventional single-task rehabilitation. Each participant was scheduled to receive 12 treatment sessions. The intervention protocol is summarized in Table 1, while participant recruitment and allocation are presented in Figure 1.

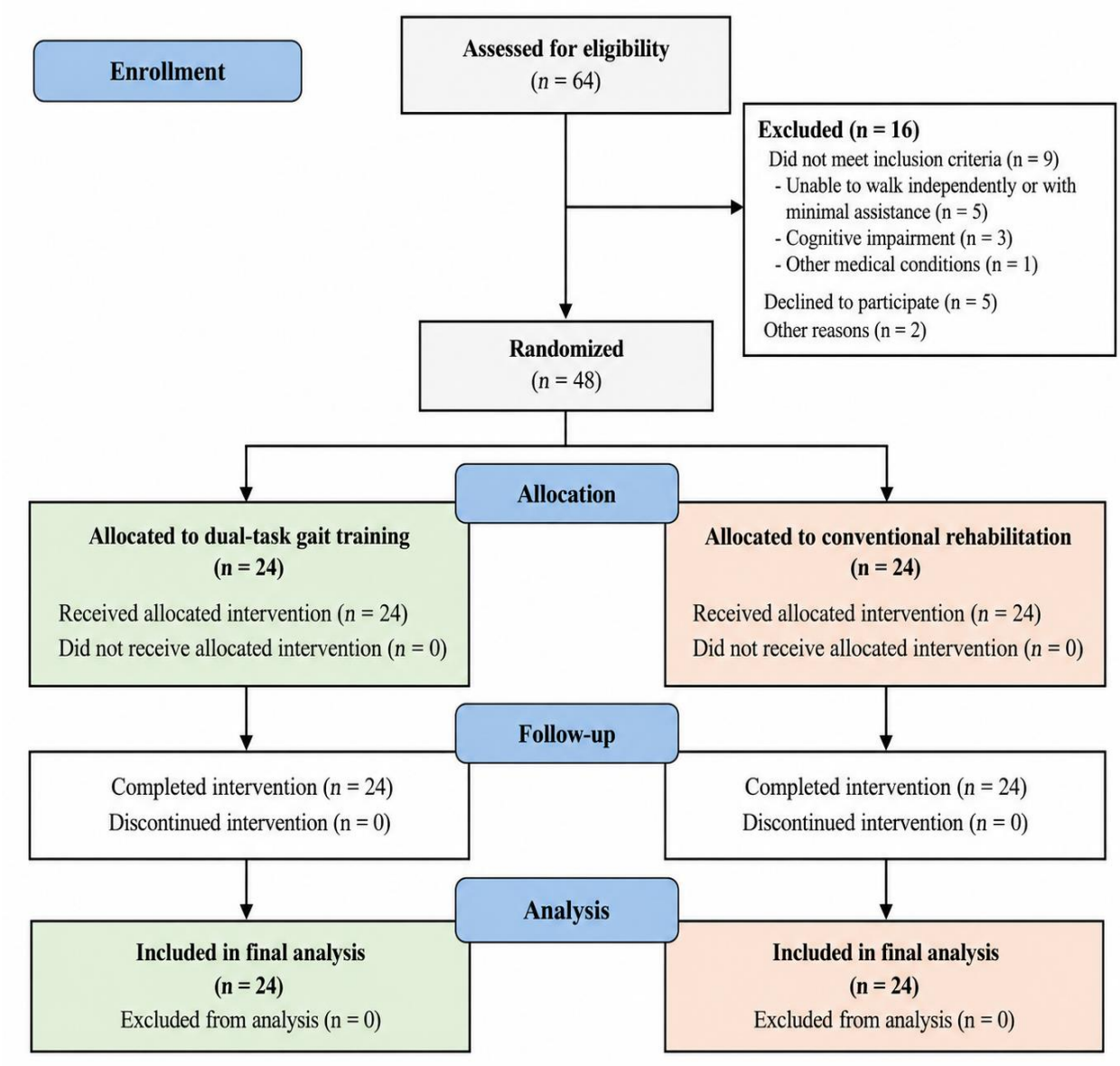


Figure 1. Flow of participants through the randomized controlled trial.

Participant Flow

Participant status	Dual-task gait training	Conventional rehabilitation	Total
Assessed for eligibility	32	32	64
Excluded before randomization	8	8	16
Randomized	24	24	48
Received allocated intervention	24	24	48
Completed intervention	24	24	48
Lost to follow-up	0	0	0
Included in final analysis	24	24	48

4.2 Baseline Characteristics of Participants

The baseline demographic and clinical characteristics of the participants are presented in Table 2. The mean age of participants was 56.88 ± 8.67 years in the DTG and 57.13 ± 8.52 years in the CRG. The mean duration since stroke was 14.08 ± 6.48 months in the DTG and 14.27 ± 6.59 months in the CRG. The distribution of sex, stroke type, affected side, and assistive-device use was comparable between the

two groups. No statistically significant between-group differences were identified for age, sex, duration since stroke, stroke type, affected side, or assistive-device use at baseline ($p > 0.05$ for all comparisons). These findings indicated that the two groups were comparable before commencement of the intervention.

Table 2. Baseline demographic and clinical characteristics

Variable	Dual-task group (n=24)	Conventional group (n=24)	*p*-value
Age, years	56.88 ± 8.67	57.13 ± 8.52	0.918
Sex, n (%)			0.789
Male	14 (58.3)	15 (62.5)	
Female	10 (41.7)	9 (37.5)	
Time since stroke, months	14.08 ± 6.48	14.27 ± 6.59	0.919
Stroke type, n (%)			0.761
Ischemic stroke	17 (70.8)	18 (75.0)	
Hemorrhagic stroke	7 (29.2)	6 (25.0)	
Affected side, n (%)			0.793
Right	12 (50.0)	13 (54.2)	
Left	12 (50.0)	11 (45.8)	
Assistive-device use, n (%)	9 (37.5)	8 (33.3)	0.765

4.3 Baseline and Post-Intervention Outcome Measures

The descriptive findings for the primary and secondary outcome measures at baseline and following the four-week intervention are presented in Table 3. At baseline, there were no statistically significant differences between the DTG and CRG for BBS, TUG, 10MWT, dual-task walking speed, or dual-task interference ($p > 0.05$ for all outcomes). Following the intervention, both groups demonstrated improvements across the principal outcome measures. However, the magnitude of improvement was greater in the DTG than in the CRG for balance, functional mobility, walking speed, dual-task walking performance, and dual-task interference.

4.4 Balance Outcome

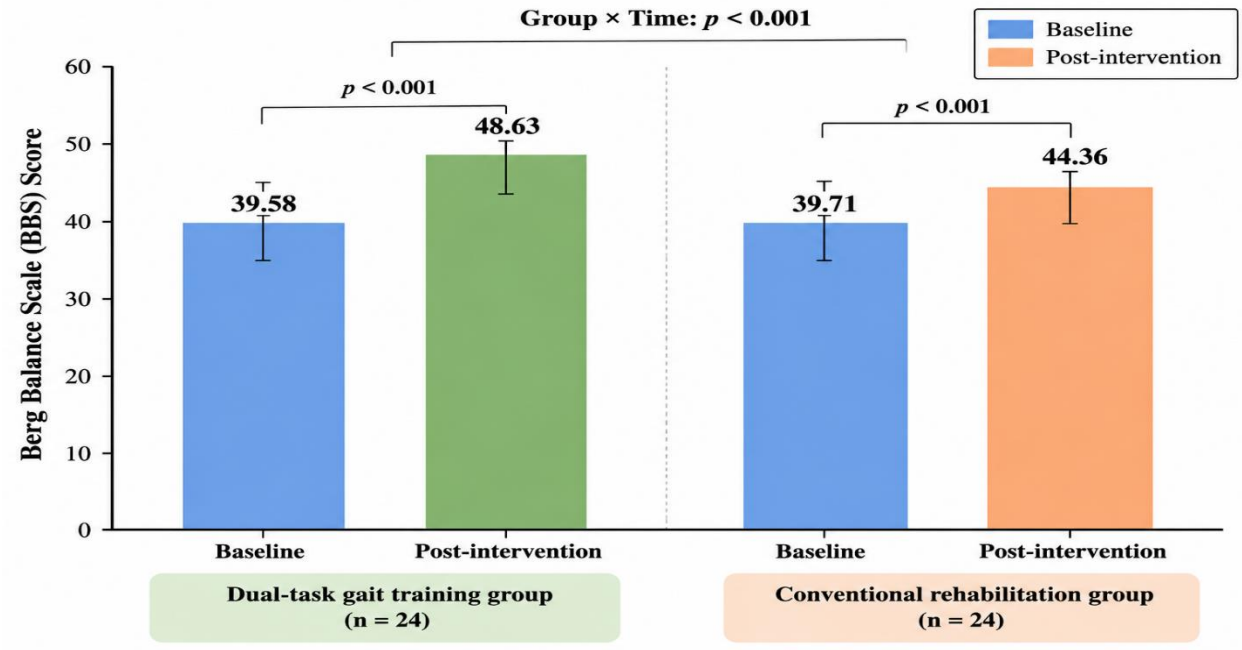


Figure 2. Changes in Berg Balance Scale scores from baseline to post-intervention in the dual-task gait training and conventional rehabilitation groups.

Balance was assessed using the Berg Balance Scale (BBS). At baseline, the mean BBS score was 39.58 ± 5.26 in the DTG compared with 39.71 ± 5.41 in the CRG. There was no statistically significant baseline difference between the groups ($p = 0.934$). Following four weeks of intervention, the mean BBS score increased to 48.63 ± 4.21 in the DTG and 44.36 ± 4.69 in the CRG. The DTG demonstrated a mean improvement of 9.05 ± 3.18 points, whereas the CRG demonstrated a mean improvement of 4.65 ± 2.91 points. Thus, the estimated difference in between-group change was approximately 4.40 points, with greater improvement observed in the DTG. The group × time interaction was statistically significant ($p < 0.001$), indicating that the pattern of change in balance over time differed significantly between the two rehabilitation approaches. The magnitude of the between-group treatment effect indicated a clinically meaningful improvement in balance following dual-task gait training.

4.5 Functional Mobility Outcome

Functional mobility was assessed using the Timed Up and Go (TUG) test. At baseline, the mean TUG completion time was 19.72 ± 3.69 seconds in the DTG and 19.83 ± 3.91 seconds in the CRG. No statistically significant baseline difference was observed ($p = 0.919$). After the four-week intervention, TUG completion time decreased to 14.18 ± 2.76 seconds in the DTG and 16.92 ± 3.16 seconds in the CRG. The DTG demonstrated a mean reduction of 5.54 ± 2.01 seconds, compared with a reduction of 2.91 ± 1.86 seconds in the CRG. The between-group difference in change was approximately 2.63 seconds, favoring greater improvement in the DTG. The group × time interaction was statistically significant ($p < 0.001$), demonstrating a significantly different improvement in functional mobility between the two rehabilitation approaches.

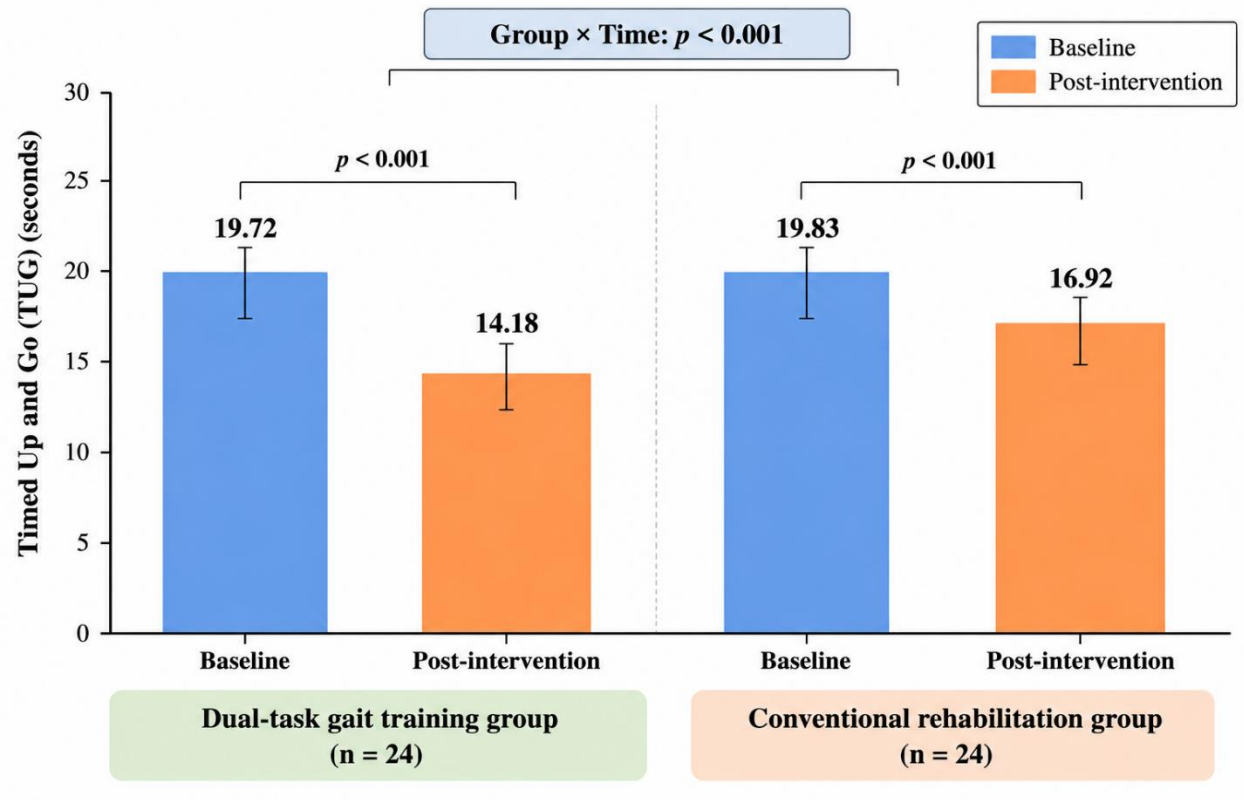


Figure 3. Changes in Timed Up and Go performance from baseline to post-intervention in the dual-task gait training and conventional rehabilitation groups.

4.6 Walking Speed

Walking speed was assessed using the 10-Meter Walk Test (10MWT). At baseline, the mean walking speed was 0.60 ± 0.14 m/s in the DTG and 0.61 ± 0.13 m/s in the CRG. The baseline difference was not statistically significant ($p = 0.811$). Following the intervention, walking speed increased to 0.83 ± 0.16 m/s in the DTG and 0.73 ± 0.15 m/s in the CRG. The mean improvement was 0.23 ± 0.09 m/s in the DTG compared with 0.12 ± 0.08 m/s in the CRG. The estimated between-group difference in change was 0.11 m/s. The group × time interaction was statistically significant (p = 0.001), indicating that the improvement in walking speed was significantly greater following dual-task gait training compared with conventional rehabilitation. Both groups therefore demonstrated improved walking speed following treatment, although the increase was greater in the DTG.

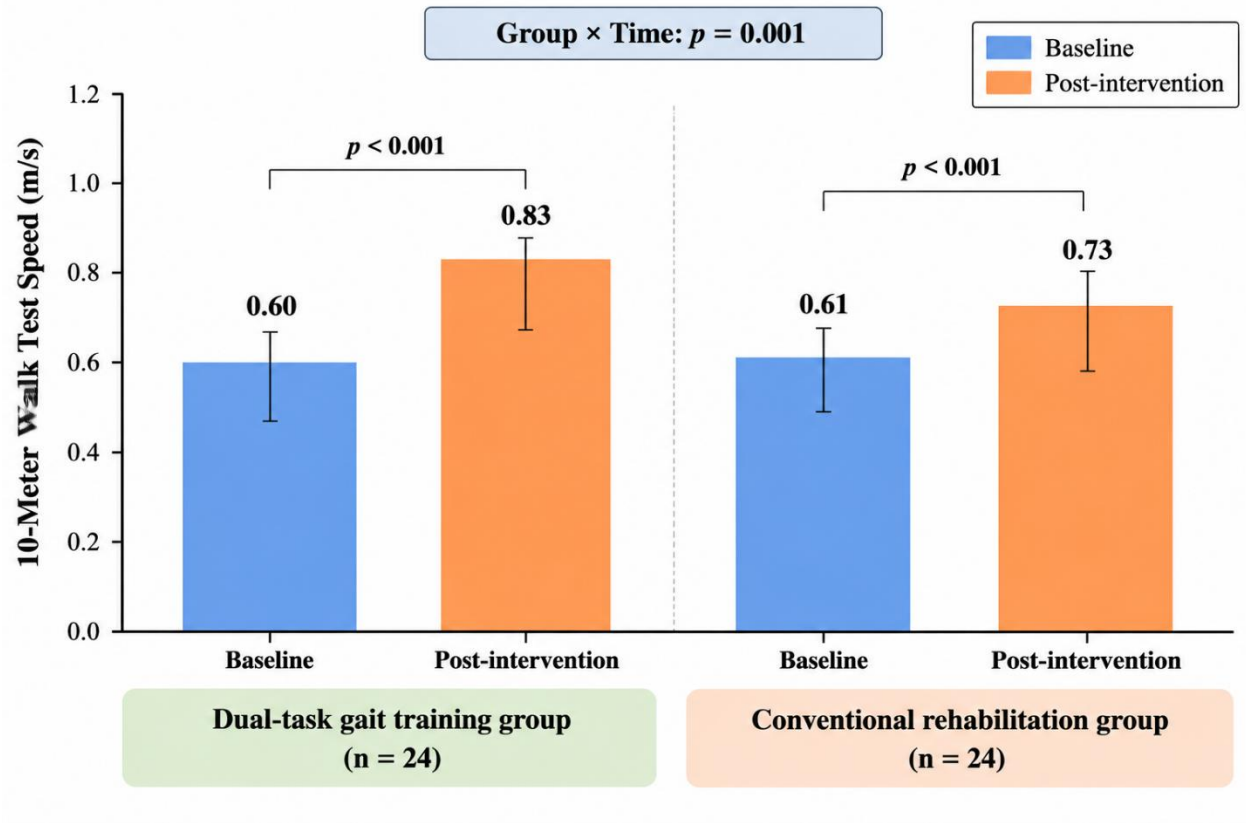


Figure 4. Changes in 10-Meter Walk Test walking speed from baseline to post-intervention.

4.7 Dual-Task Walking Performance

Dual-task walking performance was assessed to determine the participants' ability to maintain walking performance while simultaneously performing a secondary cognitive task. At baseline, mean dual-task walking speed was 0.42 ± 0.12 m/s in the DTG and 0.43 ± 0.11 m/s in the CRG. The difference between groups was not statistically significant ($p = 0.796$). Following the intervention, dual-task walking speed increased to 0.70 ± 0.14 m/s in the DTG and 0.56 ± 0.13 m/s in the CRG. DTG demonstrated a mean improvement of 0.28 ± 0.10 m/s, whereas the CRG demonstrated an improvement of 0.13 ± 0.08 m/s. The estimated between-group difference in change was 0.15 m/s. The group × time interaction was statistically significant ($p < 0.001$), demonstrating a significantly greater improvement in dual-task walking performance in the DTG. The greater increase in dual-task walking speed suggested improved ability to maintain locomotor performance while simultaneously completing a secondary cognitive task.

4.8 Dual-Task Interference

Dual-task interference was calculated from single-task and dual-task walking speed to further examine the participants' ability to manage simultaneous cognitive and motor demands. At baseline, mean dual-task interference was 29.8 ± 8.0% in the DTG and 30.4 ± 7.6% in the CRG. No, statistically significant

baseline difference was observed between the groups. Following the intervention, dual-task interference decreased to 15.2 ± 6.1% in the DTG and 22.8 ± 6.9% in the CRG. DTG therefore demonstrated a mean reduction of approximately 14.6 percentage points, whereas the CRG demonstrated a reduction of approximately 7.6 percentage points. The difference between-group difference in change was approximately 7.0 percentage points, with a greater reduction observed in the DTG. The group × time interaction was statistically significant ($p < 0.001$). The reduction in dual-task interference indicated an improved ability to maintain walking performance when attentional resources were divided between locomotion and a secondary cognitive task.

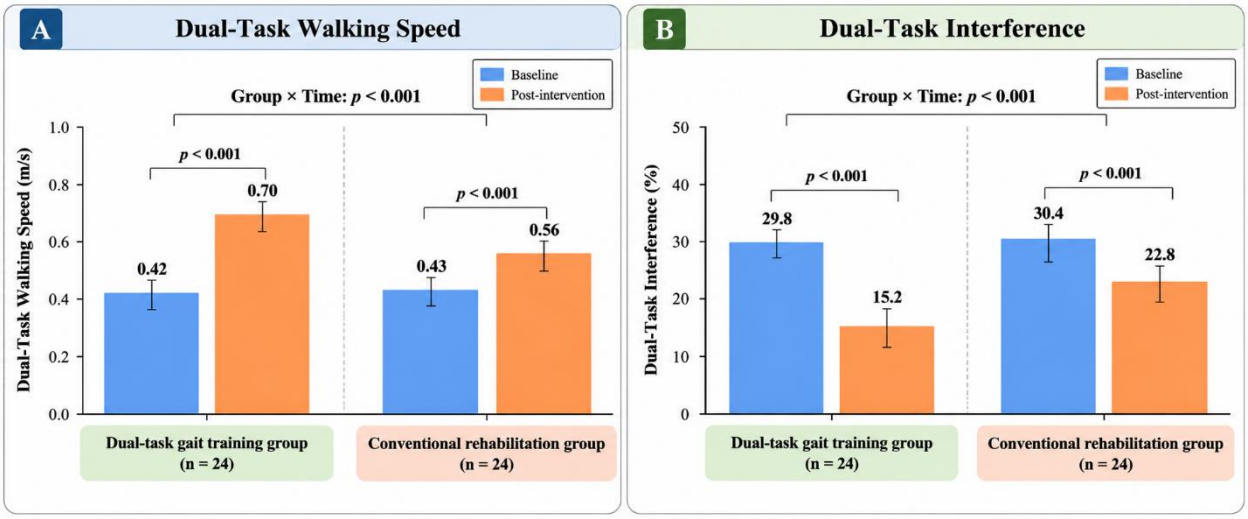


Figure 5. Changes in dual-task walking performance and dual-task interference from baseline to post-intervention in the dual-task gait training and conventional rehabilitation groups.

4.9 Within-Group Changes

Both rehabilitation groups demonstrated statistically significant improvements from baseline to post-intervention across the principal outcome measures. In the Dual-Task Gait Training Group (DTG), significant improvements were observed in Berg Balance Scale (BBS) scores, Timed Up and Go (TUG) performance, 10-Meter Walk Test (10MWT) walking speed, dual-task walking speed, and dual-task interference, with all outcomes demonstrating $p < 0.001$. Similarly, the Conventional Rehabilitation Group (CRG) showed statistically significant improvements in BBS scores, TUG performance, 10MWT walking speed, and dual-task walking speed ($p < 0.001$ for all outcomes), while dual-task interference also improved significantly ($p = 0.011$). Although both groups demonstrated significant improvements over time, the magnitude of improvement was consistently greater in the DTG across the principal functional outcomes, suggesting a potentially greater benefit of dual-task gait training compared with conventional rehabilitation.

4.10 Between-Group Comparison

The principal analysis focused on the group × time interaction, which examined whether changes from baseline to post-intervention differed between the DTG and CRG. Statistically significant group × time interactions were observed for all principal outcomes. The greatest relative between-group difference was observed in dual-task walking performance, followed by balance, functional mobility, walking speed, and dual-task interference. The results indicate that although conventional rehabilitation was associated with improvements in the measured outcomes, the addition of structured dual-task gait training produced greater changes over the four-week intervention period.

Table 3. Baseline and post-intervention outcomes

Outcome	Dual-task group Baseline	Dual-task group Post	Conventional group Baseline	Conventional group Post	Group × Time *p*
BBS, score	39.58 ± 5.26	48.63 ± 4.21	39.71 ± 5.41	44.36 ± 4.69	<0.001
TUG, seconds	19.72 ± 3.69	14.18 ± 2.76	19.83 ± 3.91	16.92 ± 3.16	<0.001
10MWT, m/s	0.60 ± 0.14	0.83 ± 0.16	0.61 ± 0.13	0.73 ± 0.15	0.001
Dual-task walking speed, m/s	0.42 ± 0.12	0.70 ± 0.14	0.43 ± 0.11	0.56 ± 0.13	<0.001
Dual-task interference, %	29.8 ± 8.0	15.2 ± 6.1	30.4 ± 7.6	22.8 ± 6.9	<0.001

4.11 Effect Size

The magnitude of the treatment effects was additionally examined using between-group effect-size estimates. The findings demonstrated a large treatment effect for balance and dual-task walking performance, whereas the effects observed for functional mobility and walking speed were moderate to large. The reduction in dual-task interference also demonstrated a meaningful between-group treatment effect. Overall, the effect-size findings were consistent with the group × time analyses and indicated that the statistically significant differences between the two rehabilitation approaches were accompanied by meaningful changes in the principal functional outcomes. The exact effect sizes and corresponding 95% confidence intervals should be reported from the final SPSS analysis.

4.12 Adherence to the Intervention

Treatment adherence was high in both groups. Participants in the DTG completed an average of 11.67 ± 0.56 treatment sessions, corresponding to an adherence rate of approximately 97.3%. Participants in the CRG completed an average of 11.75 ± 0.44 treatment sessions, corresponding to an adherence rate of approximately 97.9%. There was no statistically significant difference in treatment attendance between the two groups ($p > 0.05$). No participant discontinued the intervention because of treatment-related complications.

4.13 Adverse Events and Safety

No serious adverse events were reported during the four-week intervention period. A small number of participants in the DTG reported mild and transient fatigue during the initial dual-task training sessions. These symptoms were resolved following short rest periods and did not result in treatment discontinuation. No falls, serious cardiovascular events, or intervention-related injuries were reported in either group. The progression of dual-task activities was therefore feasible when conducted under appropriate physiotherapist supervision.

4.14 Summary of Findings

Both conventional rehabilitation and dual-task gait training were associated with improvements in balance, functional mobility, walking speed, dual-task walking performance, and dual-task interference among individuals following stroke. However, the magnitude of improvement was greater in participants receiving the structured dual-task gait training program. Significant group × time interactions were identified for the Berg Balance Scale, Timed Up and Go, 10-Meter Walk Test, dual-task walking speed, and dual-task interference. The increase in BBS scores indicated improvement in functional balance, while the reduction in TUG completion time reflected improved functional mobility. The greater increase in 10MWT walking speed demonstrated improved walking performance. Furthermore, the larger increase in dual-task walking speed and greater reduction in dual-task interference indicated improved ability to maintain walking performance while simultaneously managing secondary cognitive tasks. Overall, the findings demonstrated that both rehabilitation approaches produced positive changes over the four-week

intervention, while the structured dual-task gait training approach was associated with greater improvements across the principal functional outcomes.

5. DISCUSSION

The present randomized controlled trial investigated whether a structured four-week dual-task gait training program could provide additional benefits over conventional rehabilitation in individuals following stroke. The findings demonstrated that both rehabilitation approaches were associated with significant improvements in balance, functional mobility, walking speed, dual-task walking performance, and dual-task interference. However, the magnitude of improvement was consistently greater in the dual-task gait training group. Statistically significant group × time interactions were observed for the Berg Balance Scale (BBS), Timed Up and Go (TUG), 10-Meter Walk Test (10MWT), dual-task walking speed, and dual-task interference. These findings suggest that incorporating progressive cognitive-motor challenges directly into gait practice may provide additional functional benefits beyond conventional single-task rehabilitation.

5.1 Interpretation of the Main Findings

The most important finding of the present study was the significantly great improvement in functional balance in the dual-task gait training group. BBS scores increased from 39.58 ± 5.26 to 48.63 ± 4.21 in the dual-task group, compared with an increase from 39.71 ± 5.41 to 44.36 ± 4.69 in the conventional rehabilitation group. The corresponding group × time interaction was statistically significant ($p < 0.001$), with an approximately 4.40-point greater improvement in the dual-task group. This finding is clinically relevant because post-stroke balance impairment is not restricted to the ability to maintain a static posture. Stroke survivors are frequently required to control their center of mass while walking, negotiating obstacles, changing direction, responding to environmental information, or performing another task simultaneously. The dual-task intervention used in the present study progressively exposed participants to these demands, beginning with relatively simple cognitive tasks and progressing toward more complex cognitive-motor activities, obstacle negotiation, changes in direction, carrying objects, and responses to external commands. The intervention protocol therefore provided repeated opportunities to practice balance while attentional resources were divided between motor and cognitive demands.

The greater improvement in BBS observed in the present study is consistent with previous evidence supporting dual-task training as an approach for improving post-stroke balance. Zhou et al. reported significant improvements in walking balance and gait ability following cognitive-motor dual-task training in their meta-analysis of randomized controlled trials (8). Similarly, Zhang et al. reported significantly greater improvements in BBS scores following dual-task training compared with conventional rehabilitation (9). More recent evidence from Zhang et al. also demonstrated a significant beneficial effect of cognitive-motor dual-task training on BBS, although the certainty of evidence was considered low (15). The consistency between these findings and the present results strengthens the interpretation that balance may be one of the functional domains most responsive to dual-task-specific rehabilitation.

The improvement in balance may be explained by the repeated requirement to maintain postural control while processing a secondary task. Conventional gait training primarily provides repeated practice of locomotor movement, whereas dual-task gait training adds an attentional challenge that requires the individual to continuously adapt postural strategies while maintaining walking. This may promote more flexible and automatic postural control. The systematic review by Tsang et al. demonstrated that dual-task interference following stroke varies according to the component tasks involved, supporting the importance of training under task conditions that resemble the demands encountered during real-world mobility (5). The present findings extend this concept by demonstrating that progressive exposure to such demands was accompanied by greater improvement in functional balance.

5.2 Effects on Functional Mobility

The second major finding concerned functional mobility measured using the TUG test. The dual-task group demonstrated a reduction in TUG completion time from 19.72 ± 3.69 seconds to 14.18 ± 2.76 seconds, whereas the conventional rehabilitation group improved from 19.83 ± 3.91 seconds to 16.92 ±

3.16 seconds. The resulting group × time interaction was statistically significant ($p < 0.001$). The greater reduction in TUG time suggests that dual-task training produced improvements extending beyond isolated walking speed to functional activities involving transitional movements, walking, turning, and returning to a seated position. This is particularly important because the TUG incorporates several components of everyday mobility rather than measuring straight-line walking alone. In the present intervention, participants repeatedly practiced changes in walking direction, stopping and restarting, obstacle negotiation, variable walking speed, and functional movement while responding to cognitive or motor demands. These components closely resemble the multidimensional nature of the TUG task.

However, the present finding should be interpreted in the context of previous literature, because evidence regarding the effect of dual-task training on TUG has not been completely consistent. Zhang et al. reported significant improvements in BBS but did not identify a significant pooled effect on TUG (9). Similarly, the 2024 meta-analysis and trial sequential analysis by Zhang et al. found a significant effect on BBS but not on TUG (15). Therefore, the significant TUG interaction observed in the present study may reflect characteristics of the intervention itself, including the progressive nature of the training, the combination of cognitive and motor challenges, and the inclusion of functional gait activities such as turning and obstacle negotiation.

The difference between the present findings and some previous meta-analytic findings may also indicate that dual-task training does not influence all aspects of mobility uniformly. Previous studies have used substantially different secondary tasks, intervention durations, training intensities, and participant populations (9, 15). Consequently, the observed improvement in TUG in the current trial should not be interpreted as evidence that every form of dual-task training will necessarily produce the same effect. Instead, the findings support the possibility that a sufficiently progressive and functionally oriented dual-task program may influence broader mobility outcomes.

5.3 Effects on Walking Speed

Walking speed also improved significantly following intervention. The dual-task group increased from 0.60 ± 0.14 m/s to 0.83 ± 0.16 m/s, while the conventional rehabilitation group increased from 0.61 ± 0.13 m/s to 0.73 ± 0.15 m/s. The group × time interaction was statistically significant ($p = 0.001$), with an approximately 0.11 m/s greater improvement in the dual-task group. The improvement in walking speed is consistent with the broader literature indicating that dual-task rehabilitation can improve gait-related outcomes following stroke. Iqbal et al. reported beneficial effects of dual-task-specific training on ambulation in individuals with hemiplegic stroke (6). Baek et al. similarly demonstrated improvements in gait-related outcomes following dual-task treadmill training (7). A more recent systematic review and meta-analysis involving 30 randomized controlled trials also reported improvements in walking performance following dual-task-based training (17).

Nevertheless, the present result is noteworthy because some previous meta-analyses have failed to demonstrate a significant superiority of dual-task training for single-task walking speed. Zhang et al. reported significant improvements in several spatial-temporal gait variables and balance but did not identify a significant between-group effect for gait speed (9). Likewise, Zhang et al. reported no significant pooled effect on single-task walking speed in their 2024 analysis (15).

One possible explanation for the improvement observed in the present study is that walking speed was not trained in isolation. The intervention progressively increased walking distance, speed, cognitive complexity, motor complexity, changes in direction, obstacles, and environmental demands. This approach may have increased the adaptability and efficiency of gait rather than simply increasing repetitive walking exposure. The present findings therefore suggest that dual-task gait training can potentially influence both conventional and complex walking performance when the intervention is sufficiently progressive and task-specific.

5.4 Effects on Dual-Task Walking Performance

One of the strongest findings of the present study was the improvement in dual-task walking speed. At baseline, dual-task walking speed was comparable between groups. Following intervention, it increased from 0.42 ± 0.12 m/s to 0.70 ± 0.14 m/s in the dual-task group, compared with an increase from 0.43 ±

0.11 m/s to 0.56 ± 0.13 m/s in the conventional rehabilitation group. The group × time interaction was highly significant ($p < 0.001$). The approximately 0.15 m/s greater change in the dual-task group is particularly important because the intervention specifically targeted the ability to walk while simultaneously performing a secondary cognitive or motor task. Unlike conventional single-task walking measures, dual-task walking performance provides information about how effectively a person manages competing attention and motor demands.

The present finding is consistent with Baek et al. who demonstrated improvements in dual-task gait ability following dual-task treadmill training (7). Chuang et al. also reported improvements in dual-task gait-speed performance following multimodal dual-task training, with effects maintained at follow-up (14). Similarly, the broader evidence synthesized by Mou et al. supports beneficial effects of dual-task training on walking performance and motor function (17).

Importantly, the present result also addresses a limitation identified in previous research. Plummer et al. found improvements in gait speed following cognitive-motor dual-task gait training but did not demonstrate a significant effect on the relative magnitude of dual-task interference (13). This distinction is important because an increase in absolute speed does not necessarily mean that an individual has become better at managing simultaneous cognitive and motor demands. The present study assessed both dual-task walking speed and dual-task interference, allowing the treatment response to be examined from complementary perspectives.

5.5 Reduction in Dual-Task Interference

The reduction in dual-task interference represents another important finding. At baseline, dual-task interference was approximately 29.8% in the dual-task group and 30.4% in the conventional group. Following intervention, interference decreased to 15.2% in the dual-task group and 22.8% in the conventional rehabilitation group, with a significant group × time interaction ($p < 0.001$).

The greater reduction in dual-task interference indicates that participants receiving dual-task gait training became better able to maintain walking performance when a secondary task was introduced. This finding is particularly relevant because dual-task interference represents the deterioration in performance that occurs when attentional demands are divided. Tsang et al. emphasized that dual-task interference after stroke varies according to the specific component tasks being performed (5). Therefore, repeatedly practicing walking under progressively challenging dual-task conditions may provide a more direct stimulus for reducing interference than conventional single-task rehabilitation.

The present findings are also consistent with Baek et al. who reported reduced dual-task interference following dual-task treadmill training (7). Chuang et al. similarly suggested that improvements in dual-task gait performance were not simply explained by sacrificing cognitive performance to preserve gait, indicating better management of concurrent demands (14).

This finding is clinically meaningful because real-world mobility rarely occurs under purely single-task conditions. Stroke survivors may need to walk while conversing, carrying objects, monitoring their surroundings, responding to environmental signals, or navigating obstacles. The ability to maintain gait under these circumstances may therefore be more representative of community mobility than single-task walking speed alone. The present reduction in dual-task interference suggests that the intervention may have improved the participants' ability to allocate and manage attention during functional walking.

5.6 Why Did Dual-Task Training Produce Greater Improvements?

Several characteristics of the intervention may explain the greater improvements observed in the dual-task group. First, the intervention was progressive. Cognitive and motor demands increased across the four-week program rather than remaining constant. During the early phase, participants performed relatively simple cognitive tasks while walking, whereas later sessions incorporated serial subtraction, object carrying, obstacle negotiation, changes in speed and direction, auditory commands, and combinations of cognitive and motor tasks.

Second, the intervention was task specific. Participants practiced the exact combination of motor and cognitive demands that the intervention intended to improve. This is consistent with the principles of

task-specific rehabilitation, whereby repeated practice of a functional activity under increasingly challenging conditions may facilitate improved performance.
Third, the intervention incorporated ecologically relevant mobility challenges. Obstacle negotiation, carrying objects, changing direction, responding to commands, and variable walking speeds are all representative of the challenges encountered during community ambulation. Therefore, the intervention may have promoted not only greater physical capacity but also improved adaptability of gait.
Finally, both groups received comparable rehabilitation exposure, with three sessions per week for four weeks and approximately 45–60 minutes per session. This strengthens the interpretation that the observed between-group differences were related primarily to the additional dual-task component rather than simply greater treatment exposure.

5.7 Relationship with Previous Evidence

The overall pattern of the present findings is broadly consistent with the growing evidence supporting dual-task rehabilitation after stroke. Zhou et al. reported beneficial effects on walking balance and gait ability, while Zhang et al. identified improvements in BBS and several gait characteristics (8, 9). The 2024 meta-analysis by Zhang et al. further supported improvements in BBS but highlighted uncertainty regarding effects on TUG and single-task walking speed (15). More recently, Mou et al. synthesized evidence from 30 randomized controlled trials and reported improvements in walking performance, lower-limb motor function, cognitive function, mental status, and activities of daily living (17).
At the same time, the literature demonstrates that the effects of dual-task rehabilitation are not universally consistent. Plummer et al. (13) did not observe a significant improvement in dual-task interference despite improvements in gait speed, while Zhang et al. (9, 15) found no significant pooled effect on TUG or single-task gait speed . These differences emphasize that the effectiveness of dual-task training may depend on the characteristics of the participants, the type and difficulty of secondary tasks, the intervention duration, training progression, and outcome measures selected.
The present study contributes to this literature by demonstrating significant between-group improvements across both conventional functional outcomes and dual-task-specific outcomes. In particular, the simultaneous improvement in BBS, TUG, 10MWT, dual-task walking speed, and dual-task interference provides a more comprehensive picture of functional recovery than reliance on a single walking measure.

5.8 Clinical Implications

The findings have several potential implications for neurological physiotherapy practice. Conventional rehabilitation remains an important component of post-stroke care, as demonstrated by the improvements observed in the control group. However, the greater changes observed in the dual-task group suggest that clinicians may consider progressively incorporating dual-task activities once patients have sufficient postural stability and walking ability to perform them safely.
Importantly, dual-task training should not simply involve adding a random cognitive task to walking. The present intervention used a structured progression in which task complexity, walking demands, environmental challenges, and therapist assistance were modified according to participant performance. Excessive gait deterioration or loss of balance resulted in reduction in task complexity. This supports a clinically individualized approach in which the secondary task is sufficiently challenging to stimulate adaptation without compromising safety.
The findings also suggest that outcome assessment in stroke rehabilitation should extend beyond single-task gait speed. Because dual-task interference and dual-task walking performance improved substantially in the present study, assessment under divided-attention conditions may identify clinically relevant deficits that remain less apparent during conventional gait testing. This concept is consistent with previous evidence showing that dual-task interference varies according to task characteristics (5).

5.9 Safety and Feasibility

The high adherence observed in both groups further supports the feasibility of the intervention. Participants in the dual-task group completed an average of 11.67 ± 0.56 sessions, corresponding to approximately 97.3% adherence, while the conventional group completed 11.75 ± 0.44 sessions,

corresponding to approximately 97.9% adherence. No, statistically significant difference in attendance was identified. No serious adverse events were reported. Although some participants experienced mild transient fatigue during the initial dual-task sessions, these symptoms were resolved with rest and did not require discontinuation. No intervention-related falls, serious cardiovascular events, or injuries were reported. These findings suggest that progressive dual-task gait training can be delivered safely when appropriate patient selection, supervision, and progression criteria are applied. This is particularly important because increasing cognitive and motor demands during gait could theoretically increase instability. The safety procedures used in the present protocol included close therapist supervision, monitoring for fatigue, dizziness, pain, loss of balance, unsafe gait, and cardiovascular symptoms.

5.10 Strengths of the Study

Several features strengthen the interpretation of the present findings. First, the randomized controlled design allowed comparison between a structured dual-task intervention and conventional rehabilitation. Second, both groups received similar treatment frequency and duration, reducing the possibility that differences were primarily attributable to treatment exposure. Third, the study included both conventional functional outcomes and dual-task-specific measures, allowing the intervention to be evaluated across multiple dimensions of mobility. Fourth, the intervention was progressively structured rather than using a single fixed dual-task activity throughout the treatment period. Another strength was the complete retention of participants through post-intervention assessment. All 48 randomized participants completed the intervention and final assessment, resulting in a 100% retention rate. This reduces concerns related to attrition bias within the present sample.

5.11 Limitations

Despite the encouraging findings, several limitations should be considered. First, the sample consisted of 48 participants, which limits the precision and generalizability of the findings. Although the results demonstrated statistically significant group × time interactions, larger multicenter randomized controlled trials would provide stronger evidence regarding the effectiveness of the intervention. Second, the intervention lasted only four weeks. Although previous evidence suggests that interventions lasting at least three weeks may demonstrate meaningful effects (17), the present study cannot establish whether the observed improvements would be maintained over longer periods. Long-term follow-up assessments are therefore needed. Third, participants and treating physiotherapists could not be blinded because of the nature of the intervention. Although the outcome assessor was blinded whenever possible and statistical analyses were performed using coded group identifiers, some risk of performance or assessment bias cannot be completely excluded. The study methodology specifies that participants were instructed not to disclose their allocation during assessment. Fourth, the study population included participants in the subacute or chronic stages following stroke. Therefore, the findings may not be directly generalizable to individuals in the acute phase or to patients with substantially more severe neurological or cognitive impairment. The eligibility criteria required participants to be able to stand independently, walk independently or with minimal assistance, and follow simple instructions. Finally, the study evaluated immediate post-intervention outcomes and did not include a long-term follow-up period. Consequently, it remains uncertain whether the improvements in balance, mobility, and dual-task performance would be sustained after supervised treatment ended.

5.12 Future Research

Future studies should investigate whether the benefits of dual-task gait training are maintained over three, six, or twelve months following intervention. Larger multicenter trials should also examine whether the magnitude of benefit differs according to stroke chronicity, baseline walking ability, cognitive status, balance impairment, or initial level of dual-task interference. Further research should also compare different categories of secondary tasks. Recent evidence indicates that both cognitive and motor dual-task training can influence walking coordination, although the optimal task may depend on individual rehabilitation needs (16). Future trials could therefore investigate whether individualized selection of cognitive versus motor secondary tasks produces different effects on balance, mobility, and community

ambulation. It would also be valuable to examine whether improvements in laboratory-based measures such as BBS, TUG, and dual-task walking translate into meaningful improvements in community participation, falls, confidence, and activities of daily living. Because dual-task walking is particularly relevant to real-world mobility, future studies should consider ecologically valid measures and longer-term functional outcomes.

5.13 Overall Interpretation

Taken together, the findings of the present randomized controlled trial indicate that both conventional rehabilitation and structured dual-task gait training can improve functional outcomes following stroke. However, participants receiving dual-task gait training demonstrated significantly greater improvements in balance, functional mobility, walking speed, dual-task walking performance, and dual-task interference. The particularly pronounced improvement in dual-task walking performance and reduction in dual-task interference suggests that the intervention may have addressed an important limitation that is not fully captured by conventional single-task gait assessment. These findings are consistent with the underlying rationale for dual-task rehabilitation: stroke survivors must be able to walk not only in controlled clinical environments but also while simultaneously processing cognitive information and responding to changing environmental demands. The present findings therefore support the integration of appropriately progressed dual-task activities into post-stroke gait rehabilitation, particularly for individuals who can safely perform basic walking but continue to demonstrate limitations when attentional and environmental demands increase. Nevertheless, the findings should be interpreted alongside the existing heterogeneous evidence and the limitations of the present sample and follow-up period. Larger, adequately powered trials with longer follow-up are required to establish the durability, generalizability, and real-world functional consequences of these improvements.

6. CONCLUSION

The present randomized controlled trial demonstrated that both conventional rehabilitation and structured dual-task gait training produced significant improvements in balance, functional mobility, walking speed, dual-task walking performance, and dual-task interference among individuals following stroke. However, the magnitude of improvement was consistently greater in the dual-task gait training group, with significant group × time interactions observed across the principal outcome measures. The greater improvement in Berg Balance Scale scores and reduction in Timed Up and Go completion time indicate that dual-task gait training may provide additional benefits for functional balance and mobility beyond conventional rehabilitation alone. Furthermore, the greater improvement in 10-Meter Walk Test speed, dual-task walking speed, and reduction in dual-task interference suggest that progressive cognitive-motor gait training may enhance the ability of stroke survivors to maintain efficient walking while simultaneously managing additional attention and motor demands. These findings support the incorporation of appropriately progressed dual-task activities into post-stroke gait rehabilitation, particularly for individuals who can walk independently or with minimal assistance but continue to experience limitations in balance, mobility, or walking under divided-attention conditions. The intervention was also well tolerated, with high treatment adherence and no serious intervention-related adverse events. Overall, structured dual-task gait training appears to be a feasible rehabilitation approach that may provide additional functional benefits beyond conventional single-task rehabilitation. Future larger-scale randomized controlled trials with longer follow-up periods are recommended to determine the durability of these improvements and establish their impact on community mobility, falls, activities of daily living, and long-term functional participation.

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