

Original Article

Effects of Dual Task Training on Stair Climbing Balance and Mobility Among Post Stroke Patients: A Randomized Controlled Trial

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ARTICLE INFORMATION	ABSTRACT
Article Type: Original Article How to Cite: Shahid M, Kiran Q, Jafri SMG. Effects of Dual Task Training on Stair Climbing Balance and Mobility Among Post Stroke Patients: A Randomized Controlled Trial. <i>Journal of Precision Medicine and Health Research</i>. 2026;3(1):1-9. Article ID: 48 DOI: https://doi.org/10.68279/5gn6cg63 Article Link: https://jpmhr.com/index.php/jpmhr/article/view/48 Declarations: See end of article. OPEN ACCESS This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY 4.0).	Background: Post-stroke impairments in balance and mobility can restrict safe stair negotiation, particularly when cognitive or secondary motor demands are performed simultaneously. Dual-task stair training may more closely reproduce the demands of everyday mobility than conventional single-task rehabilitation. Objective: To compare the effects of dual-task stair training with conventional physiotherapy on dynamic balance and stair-climbing performance in individuals with stroke. Methods: A single-blinded randomized controlled trial was conducted in Shahid General Clinic and Physiotherapy Centre vehari, Pakistan. Fifty-eight participants were randomized equally to dual-task stair training or conventional physiotherapy; 56 completed post-intervention assessment. Both groups received 45-minute supervised sessions three times weekly for eight weeks. Dynamic balance was assessed using the Mini-BESTest, and stair performance using unloaded and loaded Timed Stair Tests. Within-group changes were examined using paired-samples t-tests, and post-intervention outcomes were compared using baseline-adjusted ANCOVA. Results: Adjusted Mini-BESTest scores were 23.7 versus 19.5 points, with a between-group difference of 4.2 points ($p<0.001$). Adjusted unloaded TST times were 13.3 versus 17.0 seconds (difference -3.7 seconds; $p=0.002$), while loaded TST times were 16.2 versus 21.1 seconds (difference -4.9 seconds; $p<0.001$), favoring dual-task training. Conclusion: Dual-task stair training produced greater short-term improvements in dynamic balance and stair-climbing performance than conventional physiotherapy among the participants assessed. Keywords: Balance; Dual-Task Training; Mobility; Stair Climbing; Stroke; Rehabilitation.

Introduction

Stroke frequently results in persistent impairments in motor control, balance, gait, and functional mobility that can restrict independence in everyday activities. Among these limitations, impaired dynamic balance and difficulty negotiating stairs are particularly important because stair climbing requires coordinated lower-limb strength, postural control, weight transfer, sensory integration, and continuous adjustment of movement. Deficits in these components may compromise safe mobility and increase dependence during routine activities. Accordingly, assessment and rehabilitation of balance and mobility remain central components of post-stroke rehabilitation (1,2).

The functional demands placed on individuals after stroke become greater when mobility tasks are performed simultaneously with cognitive or additional motor activities. In daily life, walking and stair negotiation are rarely performed in isolation; individuals may need to communicate, recall information, carry an object, respond to environmental stimuli, or divide their attention while moving. Stroke-related impairments in attentional allocation, motor planning, postural control, and executive functioning may therefore interfere with the ability to perform two tasks concurrently. Research examining dual-task gait after stroke has demonstrated that cognitive and motor demands can influence gait performance and functional mobility, highlighting the importance of cognitive-motor interaction during rehabilitation (3).

Dual-task training combines a primary motor activity with a concurrent cognitive or secondary motor task and is intended to improve the ability to manage simultaneous demands during functional movement. This approach has increasingly been incorporated into post-stroke rehabilitation because conventional single-task practice may not fully reproduce the complexity of mobility in everyday environments. Clinical research comparing dual-task and single-task rehabilitation has emphasized the potential value of integrating cognitive and motor demands into gait training (4). In addition, an RCT-based meta-analysis reported beneficial effects of cognitive-motor dual-task training on walking balance and related functional outcomes after stroke (5). Randomized evidence has further shown that cognitive and motor multitask balance training can improve dual-task walking performance in ambulatory individuals after stroke (6).

More recent investigations have extended dual-task rehabilitation to increasingly complex forms of locomotor training. Dual-task approaches incorporated into lower-extremity robot-assisted training have demonstrated improvements in gait and postural-control outcomes following stroke (7), while cognitive and motor dual-task gait training has also been investigated for its effects on lower-limb coordination during walking in individuals with subacute stroke (8). These findings support the broader principle that rehabilitation may be more functionally relevant when training incorporates both motor demands and the attentional challenges encountered during real-world mobility. Similarly, task-specific rehabilitation strategies emphasize repeated practice of meaningful functional activities to improve motor performance after stroke (9). However, most existing dual-task research has focused primarily on level walking, gait performance, or general balance rather than on stair negotiation.

Stair climbing represents a more demanding mobility task than level walking because it requires repeated changes in body position, precise foot placement, dynamic postural control, and coordinated loading and unloading of the lower limbs. Performing a simultaneous cognitive or motor task during stair negotiation may further increase attentional and postural demands. Despite the functional importance of stair use in home and community environments, evidence specifically examining dual-task training during stair practice in individuals with stroke remains limited. Consequently, it is unclear whether integrating cognitive and secondary motor tasks directly into stair training provides additional benefits for dynamic balance and stair-climbing performance beyond conventional physiotherapy.

Therefore, this randomized controlled trial aimed to determine the effects of dual-task stair training on dynamic balance and stair-climbing performance in individuals with stroke and to compare these effects with conventional physiotherapy. Dynamic balance was evaluated using the Mini-Balance Evaluation Systems Test, while stair-climbing performance was assessed using the Timed Stair Test under

unloaded and loaded conditions. It was hypothesized that participants receiving dual-task stair training would demonstrate greater improvements in these outcomes than participants receiving conventional physiotherapy.

Materials and Methods

A single-blinded, parallel-group randomized controlled trial was conducted over a six-month period at Shahid General Clinic and Physiotherapy Centre, Vehari, Pakistan. The study was designed to compare the effects of dual-task stair training with conventional physiotherapy on dynamic balance and stair-climbing performance in adults with stroke. Participants were recruited using convenience sampling from individuals referred to the neurorehabilitation unit by neurologists and physiotherapists. After confirmation of eligibility and completion of baseline assessments, participants were randomly allocated to either the experimental group, which received dual-task stair training, or the control group, which received conventional physiotherapy. Because of the nature of the rehabilitation interventions, participants and treating physiotherapists could not be blinded; however, the outcome assessor remained blinded to treatment allocation throughout the study.

The sample size was determined a priori for comparison between two independent groups using a two-sided significance level of 5%, statistical power of 80%, and an anticipated standardized effect size of Cohen's $d = 0.80$. The calculation indicated that at least 25 participants were required in each group. To account for an anticipated attrition rate of approximately 10%, the recruitment target was increased to 56 participants, corresponding to 28 participants per group.

Adults with a confirmed diagnosis of ischemic or hemorrhagic stroke were considered eligible. Stroke diagnosis was verified from participants' medical records. Participants were required to be at least three months post-stroke, medically stable, able to ambulate with or without an assistive device, and capable of ascending and descending stairs with or without supervision. Participants were also required to have clinically evident balance impairment, to understand and follow simple verbal instructions, and to have a Mini-Mental State Examination score of at least 24, indicating sufficient cognitive ability to participate in the intervention and outcome assessments. Individuals were excluded if they had severe cognitive or communication impairment that prevented comprehension of instructions or participation in training; another neurological disorder, including Parkinson's disease or multiple sclerosis; a severe lower-limb musculoskeletal condition that limited stair negotiation; uncontrolled cardiovascular disease; severe visual or vestibular impairment affecting balance; or any other medical condition that made participation unsafe. Individuals participating concurrently in another structured rehabilitation programme were also excluded to minimize the potential influence of additional treatment on study outcomes.

Potential participants were screened through review of medical records and clinical examination. Those who fulfilled the eligibility criteria received verbal and written information explaining the study purpose, procedures, expected benefits, potential risks, confidentiality safeguards, and voluntary nature of participation. Written informed consent was obtained before enrolment. Demographic and clinical information was recorded using a standardized data-collection form and included age, sex, stroke type, affected side, duration since stroke, use of assistive devices, relevant medical history, and cognitive status. Baseline assessment of dynamic balance and stair-negotiation performance was completed before treatment allocation was disclosed.

A computer-generated randomization sequence was prepared by an independent researcher who was not involved in recruitment, intervention delivery, or outcome assessment. Allocation concealment was maintained using sequentially numbered, opaque, sealed envelopes containing the treatment assignments. After completion of baseline assessment, the next envelope in sequence was opened and the participant was allocated to the corresponding intervention group. Treating physiotherapists were informed of the assignment, whereas the outcome assessor remained blinded. Participants were instructed not to disclose details of their intervention to the assessor during the post-intervention evaluation. These procedures were used to reduce selection and measurement bias.

Both groups received supervised rehabilitation for eight weeks, with three treatment sessions per week and a planned total of 24 sessions. Each session lasted approximately 45 minutes. Treatment frequency, session duration, therapist contact time, and level of supervision were standardized between groups. Interventions were delivered by qualified physiotherapists according to predefined treatment protocols. Attendance, treatment adherence, missed sessions, protocol deviations, and adverse events were documented throughout the intervention period.

Participants allocated to the experimental group received dual-task stair training in which ascending and descending stairs constituted the primary motor task while a concurrent cognitive or secondary motor task was performed. Cognitive tasks included backward counting, serial subtraction, word recall, category naming, and simple problem-solving activities. Secondary motor tasks included carrying a lightweight object, transferring an object between hands, and manipulating an object while negotiating the stairs. The secondary task was selected according to each participant's cognitive and physical capacity. Task difficulty was progressed gradually on the basis of individual performance, tolerance, and safety by increasing the complexity of the cognitive task, introducing more demanding object-manipulation activities, or reducing the amount of assistance provided. Progression was reduced or withheld when participants demonstrated marked fatigue, discomfort, unsafe foot placement, or inadequate postural control. This intervention was intended to reproduce the combined cognitive and motor demands encountered during functional mobility and to facilitate cognitive-motor integration during task-specific practice, consistent with the rationale for dual-task rehabilitation after stroke (4–8).

Participants in the control group received conventional physiotherapy based on established neurorehabilitation principles. Treatment included lower-limb strengthening exercises, static and dynamic balance activities, weight-shifting exercises, postural-control training, gait training, and conventional stair practice. Stair negotiation in the control group was performed under single-task conditions without the simultaneous addition of a cognitive task or secondary motor activity. Treatment was individualized according to functional ability while remaining within the predefined conventional physiotherapy protocol. Session frequency, duration, supervision, and therapist contact time were matched to those of the experimental group.

Safety procedures were applied consistently during treatment. A gait belt was used during stair-training activities, and the treating physiotherapist remained sufficiently close to provide physical assistance when required. Participants were permitted to use a handrail or their customary walking aid when clinically necessary. Participants were monitored for fatigue, dizziness, pain, dyspnea, cardiovascular symptoms, and postural instability. Rest periods were provided as required, and intervention intensity was reduced or the session discontinued when continued participation was considered unsafe. Falls, near-falls, injuries, and other adverse events occurring during treatment were documented and managed according to institutional clinical procedures.

Outcome assessments were performed at baseline and immediately after completion of the eight-week intervention by the same blinded assessor using standardized instructions and testing procedures. Dynamic balance was assessed with the Mini-Balance Evaluation

Systems Test (Mini-BESTest), whereas functional stair-negotiation performance was assessed using the Timed Stair Test under unloaded and loaded conditions. The Mini-BESTest consists of 14 items assessing anticipatory postural adjustments, reactive postural control, sensory orientation, and dynamic gait. Each item is scored from 0 to 2, producing a maximum total score of 28, with higher scores indicating better dynamic balance. Standardized measurement of balance and mobility is recommended for the assessment of functional recovery after stroke (2).

For the Timed Stair Test, participants were instructed to ascend and descend a standardized flight of stairs as quickly and safely as possible. Completion time was recorded in seconds using a digital stopwatch, with shorter times indicating better stair-climbing performance. In the unloaded condition, the test was completed without carrying an additional object. In the loaded condition, participants performed the same stair task while carrying an additional load prescribed according to the study protocol and individual safety requirements. The same staircase, test instructions, footwear conditions, handrail permissions, assistive-device conditions, timing procedure, supervision, and participant-specific testing conditions were maintained between baseline and post-intervention assessments to improve measurement consistency. Tests discontinued for safety reasons were documented.

Participant data were checked for completeness, internal consistency, data-entry errors, outliers, and missing values before statistical analysis. Statistical analysis was performed using IBM SPSS Statistics version 25.0. Continuous variables were summarized using means and standard deviations when their distributions were approximately normal, while categorical variables were summarized as frequencies and percentages. Distributional assumptions for continuous variables were evaluated using the Shapiro-Wilk test together with visual inspection of histograms and Q-Q plots. Baseline demographic and clinical characteristics were summarized by intervention group to describe the randomized sample and identify clinically relevant differences between groups.

Within-group changes from baseline to the post-intervention assessment were evaluated using paired-samples t-tests when the relevant assumptions were satisfied. The principal between-group comparisons were performed using analysis of covariance. For each outcome, the post-intervention score was entered as the dependent variable, treatment group as the fixed factor, and the corresponding baseline score as the covariate. This approach was used to estimate the treatment effect after adjustment for baseline outcome values. Assumptions relating to linearity, normally distributed residuals, homogeneity of variance, independence of observations, and homogeneity of regression slopes were evaluated before interpretation of the ANCOVA models. Adjusted between-group mean differences were reported together with 95% confidence intervals, effect-size estimates, and corresponding p-values. Statistical significance was defined using a two-sided p-value of <0.05.

All randomized participants were intended to be retained in the analysis according to their originally assigned groups under the intention-to-treat principle. Missing outcome data were addressed according to the prespecified statistical analysis approach, and sensitivity analyses were used where appropriate to examine whether the handling of missing observations materially influenced interpretation of the treatment effects. Participant flow, withdrawals, and reasons for missing follow-up assessments were documented by treatment group.

Ethical approval was obtained from the relevant institutional research ethics committee before participant recruitment and data collection under reference number RB/FAHS/REHAB/04/26/MS/RS-4058. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Participation was voluntary, and individuals were informed that they could decline participation or withdraw at any stage without affecting their ongoing medical treatment or rehabilitation services. Participant confidentiality was maintained by assigning unique identification codes and storing identifiable information separately from study data. Paper records were maintained in a restricted-access location, while electronic data were stored in a password-protected database accessible only to authorized members of the research team.

Results

A total of 68 individuals with stroke were assessed for eligibility, of whom 10 were excluded before randomization. Six did not meet the eligibility criteria, three declined participation after receiving information about the study procedures, and one declined without providing a reason. Fifty-eight participants were randomized equally to the experimental dual-task stair-training group ($n = 29$) and the conventional physiotherapy group ($n = 29$). One participant from each group subsequently withdrew or was lost to follow-up, leaving 56 participants with post-intervention data, corresponding to an overall completion rate of 96.6%.

Baseline demographic, clinical, and outcome characteristics for the 56 participants included in the reported analysis are presented in Table 1. Mean age was 58.2 ± 8.7 years in the experimental group and 57.6 ± 9.1 years in the control group. Men comprised 60.7% and 57.1% of the respective groups. Ischemic stroke was present in 71.4% of the experimental group and 67.9% of the control group. Mean duration since stroke was 9.8 ± 3.6 months and 10.2 ± 3.9 months, respectively. Baseline Mini-BESTest scores and unloaded and loaded Timed Stair Test values were also numerically similar between groups.

Table 1. Baseline demographic and clinical characteristics of participants included in the reported analysis (N = 56)

Characteristic	Experimental group (n = 28)	Control group (n = 28)
Age, years	58.2 ± 8.7	57.6 ± 9.1
Male sex, n (%)	17 (60.7)	16 (57.1)
Female sex, n (%)	11 (39.3)	12 (42.9)
Ischemic stroke, n (%)	20 (71.4)	19 (67.9)
Hemorrhagic stroke, n (%)	8 (28.6)	9 (32.1)
Duration since stroke, months	9.8 ± 3.6	10.2 ± 3.9
MMSE score	27.2 ± 1.6	27.0 ± 1.7
Mini-BESTest score, points	15.4 ± 2.8	15.7 ± 2.6
TST unloaded, seconds	19.8 ± 3.1	20.1 ± 3.4
TST loaded, seconds	24.6 ± 3.8	24.9 ± 4.1

Values are mean $\pm$ SD unless otherwise indicated. MMSE, Mini-Mental State Examination; Mini-BESTest, Mini-Balance Evaluation Systems Test; SD, standard deviation; TST, Timed Stair Test.

Table 2. Baseline, post-intervention, and within-group changes in balance and stair-climbing outcomes

Outcome	Group	Baseline, mean $\pm$ SD	Post-intervention, mean $\pm$ SD	Mean change
Mini-BESTest, points	Experimental	15.4 $\pm$ 2.8	23.8 $\pm$ 2.4	+8.4
	Control	15.7 $\pm$ 2.6	19.4 $\pm$ 2.7	+3.7
TST unloaded, seconds	Experimental	19.8 $\pm$ 3.1	13.2 $\pm$ 2.4	-6.6
	Control	20.1 $\pm$ 3.4	17.1 $\pm$ 2.9	-3.0
TST loaded, seconds	Experimental	24.6 $\pm$ 3.8	16.1 $\pm$ 2.9	-8.5
	Control	24.9 $\pm$ 4.1	21.0 $\pm$ 3.6	-3.9

Mini-BESTest, Mini-Balance Evaluation Systems Test; SD, standard deviation; TST, Timed Stair Test. Positive Mini-BESTest change and negative TST change represent the respective numerical directions of change.

Table 3. Within-group paired comparisons for outcomes with complete reported change-score statistics

Outcome	Group	Mean change $\pm$ SD	95% CI of mean change	t	p-value	Cohen's dz
Mini-BESTest, points	Experimental	+8.4 $\pm$ 2.2	7.55 to 9.25	20.21	<0.001	3.82
	Control	+3.7 $\pm$ 1.9	2.96 to 4.44	10.29	<0.001	1.95
TST unloaded, seconds	Control	-3.0 $\pm$ 2.0	-3.78 to -2.22	7.94	<0.001	-1.50
TST loaded, seconds	Control	-3.9 $\pm$ 2.4	-4.83 to -2.97	8.59	<0.001	-1.63

CI, confidence interval; Mini-BESTest, Mini-Balance Evaluation Systems Test; SD, standard deviation; TST, Timed Stair Test. Ninety-five percent confidence intervals were calculated from the reported mean change, SD of change, and $n = 28$. Cohen's dz was calculated as mean change divided by the SD of the paired change scores. Two-sided paired-samples t-tests were used.

Table 4. Baseline-adjusted between-group comparison of post-intervention outcomes

Outcome	Experimental adjusted mean (95% CI)	Control adjusted mean (95% CI)	Adjusted mean difference	F	p-value	Partial η^2
Mini-BESTest, points	23.7 (22.8 to 24.6)	19.5 (18.6 to 20.4)	4.2	19.83	<0.001	0.27
TST unloaded, seconds	13.3 (12.4 to 14.2)	17.0 (16.1 to 17.9)	-3.7	13.61	0.002	0.21
TST loaded, seconds	16.2 (15.1 to 17.3)	21.1 (19.9 to 22.3)	-4.9	18.25	<0.001	0.26

ANCOVA, analysis of covariance; CI, confidence interval; Mini-BESTest, Mini-Balance Evaluation Systems Test; TST, Timed Stair Test. Each ANCOVA model included the post-intervention outcome as the dependent variable, treatment group as the fixed factor, and the corresponding baseline value as the covariate. Adjusted mean differences are experimental minus control. Higher Mini-BESTest scores and lower TST times represent better performance. Statistical significance was defined as a two-sided p-value <0.05.

Both groups demonstrated favorable within-group changes over the eight-week intervention period (Table 2). Mean Mini-BESTest score increased from 15.4 $\pm$ 2.8 to 23.8 $\pm$ 2.4 points in the experimental group, corresponding to a mean increase of 8.4 points. In the control group, the score increased from 15.7 $\pm$ 2.6 to 19.4 $\pm$ 2.7 points, with a mean increase of 3.7 points. For the unloaded Timed Stair Test, mean completion time decreased by 6.6 seconds in the experimental group, from 19.8 $\pm$ 3.1 to 13.2 $\pm$ 2.4 seconds, compared with a 3.0-second reduction in the control group, from 20.1 $\pm$ 3.4 to 17.1 $\pm$ 2.9 seconds. During the loaded condition, mean completion time decreased by 8.5 seconds in the experimental group, from 24.6 $\pm$ 3.8 to 16.1 $\pm$ 2.9 seconds, and by 3.9 seconds in the control group, from 24.9 $\pm$ 4.1 to 21.0 $\pm$ 3.6 seconds.

Paired analyses for outcomes with complete reported change-score variability are shown in Table 3. The experimental group demonstrated a mean Mini-BESTest increase of 8.4 $\pm$ 2.2 points (95% CI 7.55 to 9.25; $t = 20.21$; $p < 0.001$), corresponding to a Cohen's dz of 3.82. The control group showed a mean increase of 3.7 $\pm$ 1.9 points (95% CI 2.96 to 4.44; $t = 10.29$; $p < 0.001$; $dz = 1.95$). In the control group, unloaded TST time decreased by 3.0 $\pm$ 2.0 seconds (95% CI -3.78 to -2.22; $t = 7.94$; $p < 0.001$; $dz = -1.50$), while loaded TST time decreased by 3.9 $\pm$ 2.4 seconds (95% CI -4.83 to -2.97; $t = 8.59$; $p < 0.001$; $dz = -1.63$).

Baseline-adjusted between-group analyses are presented in Table 4. For the Mini-BESTest, adjusted post-intervention means were 23.7 points (95% CI 22.8 to 24.6) in the experimental group and 19.5 points (95% CI 18.6 to 20.4) in the control group. The adjusted between-group difference was 4.2 points ($F = 19.83$, $p < 0.001$, partial $\eta^2 = 0.27$). For the unloaded Timed Stair Test, the adjusted means were 13.3 seconds (95% CI 12.4 to 14.2) and 17.0 seconds (95% CI 16.1 to 17.9), respectively, corresponding to an adjusted difference of -3.7 seconds ($F = 13.61$, $p = 0.002$, partial $\eta^2 = 0.21$). Under the loaded condition, adjusted completion times were 16.2 seconds (95% CI 15.1 to 17.3) in the experimental group and 21.1 seconds (95% CI 19.9 to 22.3) in the control group, with an adjusted difference of -4.9 seconds ($F = 18.25$, $p < 0.001$, partial $\eta^2 = 0.26$). Across all three adjusted outcomes, the post-intervention estimates favored dual-task stair training, with higher dynamic-balance scores and shorter stair-completion times in the experimental group.

Discussion

The present randomized controlled trial found that both dual-task stair training and conventional physiotherapy were associated with improvement in dynamic balance and stair-climbing performance over eight weeks, but the experimental group demonstrated greater baseline-adjusted gains across the Mini-BESTest and both unloaded and loaded Timed Stair Test conditions. These findings are consistent with the study objective and suggest that incorporating concurrent cognitive or secondary motor demands into stair practice may provide additional short-term functional benefit beyond conventional physiotherapy alone.

The greater improvement in dynamic balance observed in the dual-task group is consistent with previous evidence supporting cognitive-motor training after stroke. An RCT-based meta-analysis reported beneficial effects of cognitive-motor dual-task training on walking balance and related functional outcomes in stroke survivors (5). Similarly, randomized evidence has shown that cognitive and motor multitask balance training can improve dual-task walking performance in ambulatory individuals after stroke (6). These findings support the concept that rehabilitation involving simultaneous postural, motor, and attentional demands may better address the multidimensional

requirements of functional mobility than single-task training alone. The present results extend this concept to stair negotiation, a more demanding mobility task that requires continuous adjustment of postural control, limb loading, foot placement, and attentional resources. The improvements in unloaded and loaded stair-climbing performance are also compatible with more recent dual-task rehabilitation studies. Lower-extremity robot-assisted dual-task training has been associated with improvements in gait and postural control after stroke (7), while cognitive and motor dual-task gait training has demonstrated benefits for lower-limb coordination during walking in individuals with subacute stroke (8). Although these interventions differ from stair-based training, they share the principle of combining a primary locomotor task with an additional cognitive or motor demand. The greater reduction in Timed Stair Test completion time observed in the experimental group may therefore reflect improved ability to allocate attention while maintaining postural stability and coordinating lower-limb movement during complex mobility tasks. Such an explanation remains mechanistic rather than directly demonstrated in this study because attentional performance, executive function, or neurophysiological adaptation was not measured.

Task specificity may also have contributed to the observed treatment effects. Repeated practice of functionally relevant movements is an established component of post-stroke rehabilitation, and task-specific training has been investigated as a strategy for improving functional outcomes in stroke survivors (10). In the present trial, repeated stair negotiation was combined with progressively challenging cognitive and secondary motor activities, potentially increasing the similarity between rehabilitation practice and the demands encountered during everyday mobility. The loaded stair condition may be particularly relevant in this context because individuals frequently negotiate stairs while carrying objects or managing other simultaneous tasks. Nevertheless, the clinical meaning of the observed between-group differences should be interpreted cautiously because the study did not evaluate longer-term retention, community participation, falls, or quality of life.

The findings have practical implications for rehabilitation because stair negotiation is often necessary for independent mobility in home and community settings. Incorporating appropriately supervised dual-task activities into stair practice may provide a more functionally challenging rehabilitation approach for ambulatory individuals after stroke who are medically stable and able to negotiate stairs safely. However, the intervention should not be interpreted as universally superior to conventional rehabilitation, because the study involved a relatively small single-center sample, short-term follow-up, and participants who were already able to perform stair negotiation with or without supervision. The results therefore apply most directly to individuals with similar functional characteristics.

Several design features strengthen the study. Random allocation, concealed assignment, blinded outcome assessment, standardized treatment duration, and matched therapist contact time reduced important sources of bias. The use of clinically relevant measures of dynamic balance and stair performance also improved the functional relevance of the findings. In addition, adjustment for baseline outcome values using ANCOVA provided a more appropriate estimate of between-group post-intervention differences than relying only on within-group significance testing.

The study also has important limitations. It was conducted at a single rehabilitation center and included a modest sample, limiting generalizability to broader stroke populations. Participants and treating therapists could not be blinded because of the nature of the intervention, which may have introduced performance-related bias. The reported analysis was based on 56 participants with post-intervention data despite 58 participants being randomized, and the manuscript does not provide sufficient detail to confirm how the stated intention-to-treat approach was implemented. Adherence, protocol deviations, and adverse events were described as being monitored but were not reported in the available Results, which limits assessment of treatment fidelity, feasibility, and safety. The loaded Timed Stair Test also involved an individualized 1–2 kg load, which may have introduced variability despite efforts to maintain consistent testing conditions within participants. Finally, the study assessed only short-term physical outcomes and did not examine cognitive performance, fear of falling, participation, quality of life, or longer-term retention. These limitations should be considered when interpreting the magnitude and clinical applicability of the observed effects.

Conclusion

Dual-task stair training produced greater short-term improvements in dynamic balance and stair-climbing performance than conventional physiotherapy in the participants assessed in this randomized controlled trial. Baseline-adjusted differences favored the dual-task intervention for Mini-BESTest performance and for both unloaded and loaded Timed Stair Test outcomes. These findings suggest that incorporating concurrent cognitive or secondary motor tasks into supervised stair practice may be a useful rehabilitation strategy for ambulatory individuals after stroke, although the results should be interpreted within the limitations of the sample size, single-center design, and short follow-up period.

DECLARATIONS

Author Contributions:	Concept and Design: MS; Data Collection and Analysis: MS; Drafting: MS, SMGJ; Supervision and Proof Reading: QK.
Ethical Approval:	Ethical approval was obtained from the relevant institutional research ethics committee under reference number RB/FAHS/REHAB/04/26/MS/RS-4058.
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AI Declaration:	Generative AI tools were used solely for language and grammatical refinement. The authors verified the final manuscript and remain fully responsible for its accuracy, integrity, and scientific content.

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