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The effect of brief, repetitive balance training on balance and fall risk in older people with stroke: A randomized controlled trial

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Abstract

Objective: To evaluate the effect of integrating a specific balance-training program focused on static balance to the conventional rehabilitation program on dynamic balance, risk of falls, and activities of daily living (ADLs) in older adults post-stroke.
Design: A single-blinded randomized controlled trial.
Setting: Institutional Intermediate Care Hospital.
Subjects: Post-stroke older adults in a subacute phase without cognitive impairment, aged 65 years and older, exhibiting trunk control in a seated position for 30 seconds without supporting the arms.
Intervention: The control group underwent the usual treatment, consisting of 60-minute physiotherapy sessions, 5 days per week, for 30 days. The experimental group integrated into the usual treatment 15 minutes of the balance-training program (45 min + 15 min).
Main measures: Balance impairment (Mini-BESTest and Berg Balance Scale (BBS), risk of falls (BBS), and independence for ADLs (Barthel Index)) were assessed at baseline, 15 and 30 days after the start of interventions.
Results: Seventy-one post-stroke patients (77.7 ± 9.0 years, 49.2% women) were randomized into the experimental ($n = 35$) or control ($n = 36$) groups. The experimental group showed improved dynamic balance at day 15 (Mini-BESTest: 2.90 [1.05–4.77], $p = 0.003$; BBS: 4.31 [1.41–7.23], $p = 0.004$) and day 30

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(Mini-BESTest: 6.06 [2.85–9.27], $p < 0.001$; BBS: 8.24 [2.96–13.53], $p = 0.003$), as well as greater independence levels (11 [2.75–19.23], $p = 0.010$) compared to the control group. The control group showed higher risk of falls on day 15 ($p = 0.035$) and day 30 ($p = 0.003$) than the experimental group.
Conclusions: A simple, easily reproducible approach designed by and for the older adult to rehabilitate post-stroke impairments effectively improved balance, functional gait, risk of falls, and ADLs.

Keywords
Stroke, rehabilitation, balance, older adults, fall risk

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Introduction

Stroke is a common and disabling global health problem. Due to post-stroke mortality has decreased due to advancements in acute, the prevalence of stroke disease doubles every decade after age 50,[1] with around 50% of cases occurring in those over 75 and 30% in those over 85.[2] Consequently, stroke is a leading cause of disability, reduced quality of life, and extended hospital stays and institutionalization in older adults.[3] Indeed, age is a well-established predictor of functional outcomes and discharge destinations in stroke patients across various studies.[4,5]

Balance and postural control impairments affect at least 83% of post-stroke survivors.[6] Common deficits in post-stroke older adults include weight-bearing asymmetry toward the nonparetic leg, increased postural sway, reduced stability limits, and impaired anticipatory postural adjustments.[6] These impairments lead to gait problems, such as reduced speed increasing the risk of falling.[7] Fall incidence in the first 6 months of post-stroke ranges from 37% to 73%, which, together to the fear of falling, further limit daily activities, reduce quality of life, and increase hospitalization, imposing emotional and economic burdens on patients, families, and society.[8]

There is a pressing need to develop and implement streamlined protocols to reduce fall risk in older post-stroke patients. While older patients may have more comorbidities, early intrahospital mobilization, even if not intense, leads to better outcomes.[9] However, balance remains a critical issue in post-stroke rehabilitation. Different physical therapies, including functional task training, biofeedback-based balance training, functional electrical stimulation, water-based exercises, virtual reality, ankle–foot orthosis, aerobic exercise, and whole-body vibration, have shown benefits in improving balance and gait in stroke survivors.[10–12] Although some studies report positive results with specific balance exercises,[13,14] most focus on dynamic balance and exclude older adults, who have a higher stroke incidence, reduced neuroplasticity, and diminished recovery potential.[15,16]

Older adults who have suffered a stroke exhibit significant alterations in static balance, such as difficulties with weight distribution or maintaining postural balance in sitting and standing positions, as well as difficulties in sitting upright and adapting to weight shifts during static adjustments (e.g. standing on one leg), which are necessary for tasks involving dynamic balance, such as walking or descending stairs.[17] The balance-training program in this study targets static balance as a foundation for improving dynamic balance.[18] A conceptual model developed several years ago identifies six domains of balance control affected by aging and neurological conditions, including stroke.[19] From this model, an exercise program for older adults was validated based on the systems described by Horak et al. (i.e. biomechanical restrictions, stability or verticality limits, anticipatory postural adjustments, postural responses, and sensory orientation), incorporating progressive exercises that simulate functional movements and require minimal cognitive effort post-stroke.[20]

The aim of this study was to evaluate the effect of adding a specific balance training program focused on static balance to the conventional rehabilitation program on dynamic balance, functional gait, risk of falls, and activities of daily living (ADLs) in older adults after stroke.

Methods

Study design and population

A parallel-group randomized controlled trial design study with blinded outcome assessment was conducted from January 2018 to October 2018. The project was approved by the Ethics Committee on Animal and Human Experimentation of the Universitat Autònoma de Barcelona and the Ethics Committee of the Universidad Internacional de Cataluña (VRIT-2017-03) and registered in Clinical Trials (ID: NCT 03406026). This randomized controlled trial (RCT) was reported in accordance with the CONSORT guidelines and fulfilled the principles of the Declaration of Helsinki.

The study participants consisted of post-stroke older adults (ischemic or hemorrhagic) in a subacute phase (i.e. 48 hours to 4 months after the stroke),[21] aged 65 years and older, admitted to the rehabilitation units in an Intermediate Care hospital in Barcelona, Spain. Participants were included if they had trunk control in a seated position for 30 seconds without supporting the arms and capacity to follow instructions. Participants were excluded if previous prestroke severe functional dependence for ADL (i.e. Barthel Index ≤ 60 points), balance impairments (i.e. due to orthopedic, neurological, or other diseases), and visual deficits were present; current aphasia (i.e. Wernicke or mixed aphasia) and delirium (assess by DSM-IV TR); and previous or post-stroke cognitive impairment (Mini-Mental State Examination score ≤ 24 points).

Randomization and blinding procedure

A researcher (Almudena Medina-Rincón) screened for potential participants. Those who met the inclusion criteria were asked to participate in the study and, if they agreed, were randomly assigned to either the intervention or the control group. A block randomization method (1:1) was used according to a computer-generated random list with the software EPIDAT v.4.1 (*Xunta de Galicia, Spain*). The allocation sequence was stored in sequentially numbered, sealed, opaque envelopes. The group assignment was secured by a code, known only by an independent administrator blinded to allocation.

Intervention

All participants underwent an equal duration of in-hospital post-stroke physiotherapy treatment, consisting of 1 hour per day for 5 days per week over a 4-week period (i.e. 20 sessions). The participants in the control group only received the usual treatment in the rehabilitation unit. In contrast, the participants in the intervention group underwent sessions divided into 45 minutes of the usual treatment combined with 15 minutes of the proposed balance-training program.

In addition to the physiotherapy treatment, all participants received post-stroke care from a multidisciplinary team. This care was tailored to meet each patient's individual needs and encompassed various components, including nursing and physician medical care, occupational therapy, logopedic treatment (if required), and caregiver/family training (when feasible).

Usual treatment

The usual treatment included exercises on muscle tone facilitation, stretching, and functional muscle strength training and gait when possible.[22] In both groups, the physiotherapy treatment was provided by a physiotherapist specialized in neurorehabilitation.

In detail, each daily session included (1) passive/assisted stretching exercises aimed at increasing the range of motion of the affected extremities and preventing contractures; (2) assisted strengthening exercises for trunk muscles and upper and lower limbs; (3) strengthening exercises in a functional

context to promote upper use and lower limb use; (4) balance exercises, initially in sitting position and then in standing position (once patient had recovered the ability to stand, even with assistance); (5) ground-floor walking first with assistance, then under supervision. The components of this physiotherapy program are widely supported by evidence in the literature.[23]

Balance-training program

The program proposed was carefully designed based on the available evidence and validated by a Delphi method in 2019.[20] All the exercises included in the program were previously described as potentially beneficial for balance impairments.[20] Detailed description of each exercise together with the number of set and repetitions, type, and progression are presented in Supplemental material.

In short, the balance training program involves nine exercises grouped into two levels of difficulty. The first level (N1) includes four exercises, and the second level (N2) has five different exercises. Participants go from N1 to N2 only in case they successfully complete all exercises of N1 (able to perform all sets and repetitions of all exercises without resting due to fatigue) and must maintain a standing position (initial position) for at least 30 seconds without external support. The aims of each level are:

Level 1: The participants must keep stable trunk control while sitting and maintaining it for 30 seconds (initial position). Then, they must tilt the trunk 30° to each side and return to the initial position. The first exercise aims to train the feet sensitivity, the second one the ankle proprioception, and the third and the fourth exercises train position changes, both from sitting to standing, and vice versa with the feet first in parallel and then the paretic foot in a position behind the other foot.

Level 2: Before starting this level, participants must maintain a standing position (initial position) for at least 30 seconds without external support. The first exercise aims to train instability in standing position with controlled pressure performed by the physiotherapist; the second demands proprioception adjustments while the participant stands with the eyes open on an unstable cushion. The third and fourth exercises are identical to previous, but the participants must perform them in monopodial support. Finally, the fifth aims to work the sensitivity and motor recruitment of the lower limbs in a monopodial support position eliminating visual stimulation.

Measurements and outcome measures

Assessments were carried out at admission (T0), 15 days (T1), and 30 days (T2) after admission. A trained physiotherapist blinded to treatment group allocation collected all the clinical measures.

Clinical, functional, and sociodemographic characteristics were collected at baseline (T0) (i.e. age, sex, dominant side, and caregiver presence). Clinical assessment included comorbidities (medical history of transient ischemic accident, stroke, dyslipidemia, atrial fibrillation, high blood pressure, and chronic obstructive pulmonary disease), clinical stroke characteristics ((ischemic/hemorrhagic), affected hemisphere, acute treatment received (fibrinolysis/endovascular treatment), severity onset and at admission to rehabilitation units (assessed by the National Institute of Health Stroke Scale, NIHSS, 0–30) and presence of dysphagia). Data was collected from the shared electronic clinical record. The prestroke functional capacity was collected through a direct interview with the patient or caregiver when it was not possible. Specifically, balance impairment (Mini BESTest and Berg Balance Scale (BBS)), functional gait (subscale dynamic gait), risk of falls (Berg Balance Scale), and independence for ADLs (Barthel Index) were assessed.

The primary outcome measure was the participants' dynamic balance assessed by the Mini BESTest[24] and BBS.[25] The Mini BESTest, a 14-item scale (0–28 points), measures the dynamic balance capacity (i.e. anticipatory postural adjustments, reactive postural control, and sensory orientation) and the dynamic gait. On the other hand, the BBS is 14 items (0–56 points) in which the patient is asked to maintain several standing positions and to perform several balance tasks of

increasing difficulty. The BBS has been reported as reliable and valid for post-stroke patients,[26] scores of under 31 points are associated with a higher risk of falls.[27]

The secondary outcomes were functional gait, risk of falls, and independence for ADLs measured by the dynamic gait subscale of Mini BESTest, BBS, and Barthel Index, respectively. All of them were assessed at baseline, T1 and T2. The Barthel Index ranges from 0 (complete dependence to perform ADL) to 100 (complete independence to perform ADL).[28]

Additionally, adherence to treatment sessions and the occurrence of any adverse effects were registered for both groups.

Sample size calculation and statistical analysis

The sample size calculation was based on the main outcomes: dynamic balance, gait, and fall risk, assessed using the Mini BESTest and BBS. Standard deviations were set at 5 for the Mini BESTest and 8 for the BBS, with minimal detectable changes of 4 and 6 points, respectively.[29,30] To achieve 80% statistical power with a 5% significance level, 58 participants (29 per group) were required. However, accounting for a potential 20% dropout rate, the total sample size was increased to 72 participants.

The statistical analysis was performed using SPSS Statistics v.28 (*IBM Corp., Chicago, IL*). The intention-to-treat approach was used, and missing data were handled using the last observation carried forward method. The person who conducted the analyses was not aware of the group allocation. The significance level for all tests was set at $p \leq 0.05$.

To analyze the data distribution, the Shapiro–Wilk test was used. Continuous variables were presented as either median and interquartile ranges or mean and standard deviation, depending on their distribution, while categorical variables were presented as percentages.

To assess the baseline comparability between the treatment groups at the beginning of the study, the Student's t-test or the Mann–Whitney U-test (for non-normally distributed data) was used for quantitative variables, and the Fischer's exact F test was used for qualitative variables.

To evaluate the effects of treatment interventions at 15 (T1) and 30 days (T2), linear mixed models adjusted for baseline values were used. The individual Friedman's analysis of variance (ANOVA) was used to test the changes over time within each treatment group for primary and secondary outcomes. Linear mixed models with group (control and experimental) as a between-factor and time (baseline, T1 and T2) as a within-factor were used to investigate differences in the trajectory over time between the two groups, using the interaction time*group. For comparisons between groups at different time points and for within-group time changes, the Bonferroni correction was used. The Greenhouse-Geisser correction was applied to address violations of sphericity. Effect sizes were calculated using Cohen's d statistic ($d > 0.8$ large effect, $d > 0.5$ moderate effect, and $d > 0.2$ small effect).

To evaluate group risk of falls differences, Chi-squared tests were used. Participants were classified at risk if their total score on the BBS was inferior to 31 points.

Results

A total of 168 post-stroke potential participants were screened; 73 were eligible, but only 71 were included and randomized (35 in control and 36 in experimental group) as 2 of them did not want to participate in the study. In total, 65 (91.5%) participants completed the 20 treatment sessions and were evaluated at T2. There were two dropouts before T1 (one participant from the control group and another from the experimental group) and four dropouts after T1 (Figure 1). The mean age of the participants was 77.71 (9.01) years, 49.23% were women. The baseline characteristics of the participants are described in Table 1. No significant differences between the groups were found.

Regarding the primary outcomes, better dynamic balance was displayed by the experimental group at T1 (Mini BESTest score: 2.90 [1.05–

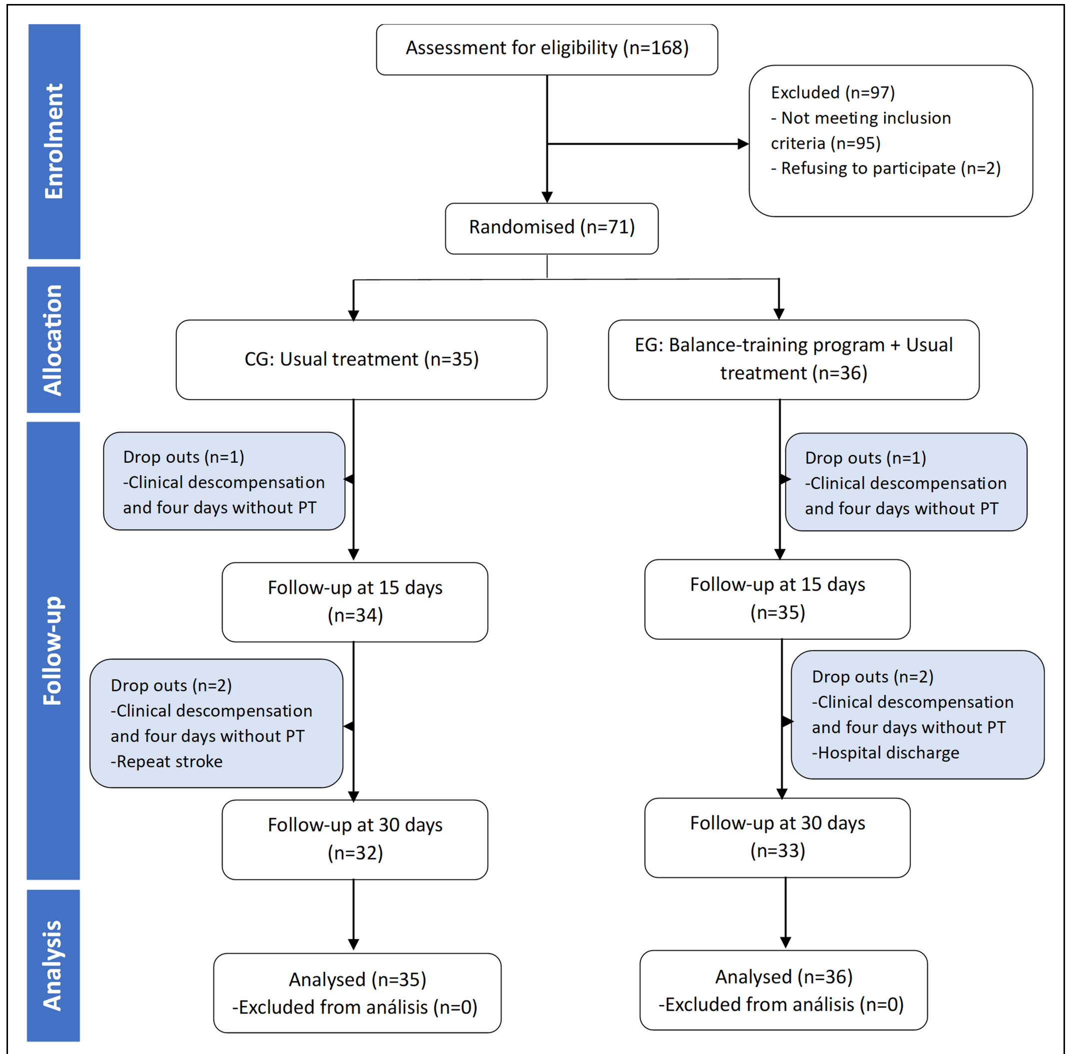

Figure 1. Participant flow chart.

4.77], $p = 0.003$, $d = 0.67$; BBS: 4.31 [1.41–7.23], $p = 0.004$, $d = 0.64$) and T2 (Mini BESTest score: 6.06 [2.85–9.27], $p < 0.001$, $d = 0.85$; BBS : 8.24 [2.96–13.53], $p = 0.003$, $d = 0.75$) compared to the control group (Table 2).

For the secondary outcomes, the experimental group showed lower levels of disability in the Barthel test at T1 (9.44 [4.23–14.65], $p < 0.001$, $d = 0.64$) and T2 (11 [2.75–19.23], $p = 0.010$, $d = 0.60$) compared to the control group (Table 2).

In terms of the Mini BESTest subscales, the experimental group showed better scores since T1 in the anticipatory postural adjustment (0.88 [0.39–1.37], $p < 0.001$, $d = 0.74$) and the reactive postural response (1.09 [0.58–1.60], $p < 0.001$, $d = 0.53$) compared to the control group. Moreover, the experimental group displayed at T2 better scores than the control group in all subscales (anticipatory postural adjustment: 1.48 [0.81–2.14], $p < 0.001$, $d = 0.99$; reactive postural response: 1.30 [0.47–

Table 1. Baseline characteristics of the sample.

	Control group ($n = 35$)	Experimental group ($n = 36$)	p-Value
Sociodemographic and functional variables			
Age (years), mean (SD)	77.03 (9.56)	78.61 (8.18)	0.456[b]
Women, *n* (%)	17 (48.6)	16 (44.4)	0.814[c]
Caregiver present, *n* (%)	19 (54.3)	24 (66.7)	0.337[c]
Previous Barthel Index[1], mean (SD)	94.71 (7.16)	95.69 (8.79)	0.269[b]
Right dominant side, *n* (%)	33 (94.3)	32 (88.9)	0.674[c]
Medical history			
Transient ischemic accident, *n* (%)	4 (11.4)	3 (8.3)	0.710[c]
Stroke, *n* (%)	6 (17.1)	4 (11.1)	0.514[c]
Dyslipidemia, *n* (%)	13 (37.1)	15 (41.7)	0.809[c]
Atrial fibrillation, *n* (%)	4 (11.4)	4 (11.1)	0.966[c]
High blood pressure, *n* (%)	31 (88.6)	27 (75)	0.220[c]
Chronic obstructive pulmonary disease, *n* (%)	4 (11.4)	3 (8.3)	0.710[c]
Clinical stroke characteristics			
Ischemic stroke, *n* (%)	30 (85.7)	32 (88.9)	0.735[c]
Carotid stenosis, *n* (%)	4 (11.4)	2 (5.6)	0.429[c]
Thrombectomy, *n* (%)	3 (8.6)	2 (5.6)	0.674[c]
Dysphagia, *n* (%)	18 (51.4)	16 (44.4)	0.638[c]
NIHSS at acute hospital, mean (SD)	10.46 (6.68)	9.42 (5.08)	0.462[a]
NIHSS at IC admission, mean (SD)	6.74 (4.59)	6.58 (4.27)	0.880[a]

Data are expressed as mean (SD) or *n* (%) for quantitative and qualitative variables, respectively.
[1]Barthel index: range from 0 to 100.
[a]Student's t-test.
[b]Mann–Whitney U test.
[c]Fisher's exact F test.
NIHSS: National Institute of Health Stroke Scale; SD: standard deviation.

2.11], $p = 0.003$, $d = 0.58$; sensory orientation: 1.35 [0.58–2.13], $p < 0.001$, $d = 0.80$; dynamic gait: 2.11 [0.70–3.56], $p = 0.005$, $d = 0.80$ (Table 2).

Regarding the group*time interaction, both groups showed significant improvements in the primary and secondary outcomes at days 15 and 30 compared to baseline. However, the experimental group showed a greater and faster improvement over time than the control group on both primary ($p < 0.008$; Figure 2) and secondary outcomes ($p < 0.002$; Figure 3).

Regarding the risk of falls, the control group had a higher proportion of participants at risk of falls on day 15 ($p = 0.035$) and day 30 ($p = 0.003$) compared to the experimental group (Figure 4).

The 76.9% of participants attended all rehabilitation sessions, performing a total of 20 hours, compared to 23.1% of participants who missed one session. In the control group: two participants missed two sessions, one participant missed three sessions, and five participants missed one session. In the experimental group: three participants missed two sessions and four participants missed one session. The motives of individuals in both groups were diverse; from family visits that coincided in schedules, urinary infection, or sadness.

No adverse effects were identified because of the treatment.

Discussion

The study results show that in older patients with stroke in subacute phase, adding 15 minutes/day of a specific balance training program for 4 weeks to conventional rehabilitation produces greater and faster improvements in balance compared to conventional rehabilitation alone. Additionally,

Table 2. Effect of the balance exercise program proposed on the outcomes measures.

	Group	Baseline	15 Days	30 Days	Adjusted mean differences [95% CI] at 15 days p-value[a] (effect size)[b]	Adjusted mean differences [95% CI] at 30 days p-value[a] (effect size)[b]	p-Value[†] time x group interaction
Mini BESTest total score	Control	3.23 (2.40)	6.43 (4.73)	10.20 (7.59)	2.90 [1.05–4.77]	6.06 [2.85–9.27]	<0.001*
	Exp.	3.67 (2.92)	9.92 (5.75)	16.86 (7.71)	0.003* (0.67)	<0.001* (0.85)	
Anticipatory subscale	Control	1.31 (1.05)	2.06 (1.43)	3.11 (1.79)	0.88 [0.39–1.37]	1.48 [0.81–2.14]	<0.001*
	Exp.	1.53 (1.15)	3.14 (1.49)	4.78 (1.57)	<0.001* (0.74)	<0.001* (0.99)	
Reactive postural control subscale	Control	0.60 (0.81)	1.14 (1.39)	2.06 (1.97)	1.09 [0.58–1.60]	1.30 [0.47–2.11]	0.001*
	Exp.	0.47 (0.65)	2.06 (1.53)	3.19 (1.91)	<0.001* (0.53)	0.003* (0.58)	
Sensory orientation subscale	Control	1.23 (1.21)	2.14 (1.47)	2.86 (1.95)	0.42 [−0.11–0.95]	1.35 [0.58–2.13]	<0.001*
	Exp.	1.36 (1.24)	2.67 (1.47)	4.31 (1.73)	0.118 (0.36)	<0.001* (0.80)	
Dynamic gait subscale	Control	0.06 (0.23)	0.77 (1.28)	2.17 (2.77)	0.73 [−0.02–1.47]	2.11 [0.70–3.56]	0.002*
	Exp.	0.25 (0.60)	1.83 (2.02)	4.58 (3.28)	0.051 (0.64)	0.005* (0.80)	
Berg Balance Scale	Control	15.49 (9.02)	20.40 (11.51)	27.26 (14.73)	4.31 [1.41–7.23]	8.24 [2.96–13.53]	0.002*
	Exp.	18.61 (10.53)	28.00 (12.35)	38.56 (15.52)	0.004* (0.64)	0.003* (0.75)	
Barthel Index	Control	36.86 (14.14)	46.43 (16.87)	61.86 (23.85)	9.44 [4.23–14.65]	11 [2.75–19.23]	0.008*
	Exp.	38.06 (16.44)	56.81 (15.59)	73.75 (17.25)	<0.001* (0.64)	0.010* (0.60)	

Data expressed as mean (SD).
*p-Value <0.05.
[†]p-Value of time x group interaction in the Linear Mixed Model after Greenhouse-Geisser correction.
[a]Mann–Whitney U test.
[b]Cohen's *d*.
CI: confidence interval; SD: standard deviation.

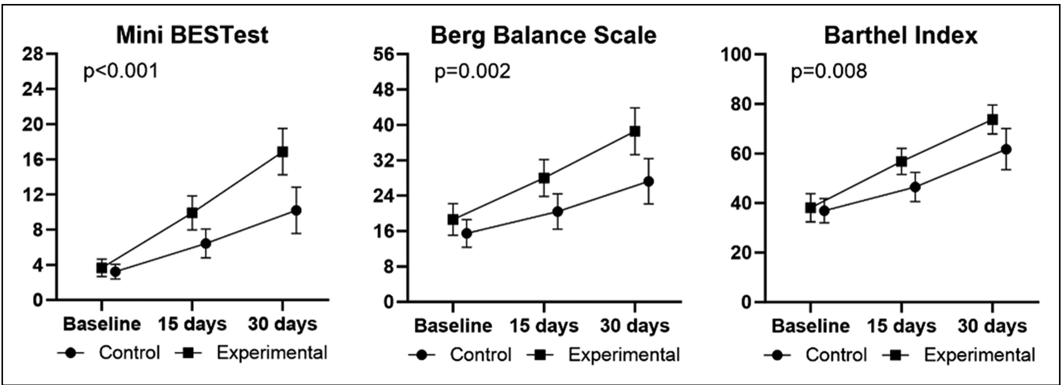

Figure 2. Changes over time on the total Mini BESTest score, Berg Balance Scale and Barthel Index according to the treatment group. The *p*-value represents the time*group interaction after Greenhouse-Geisser correction.

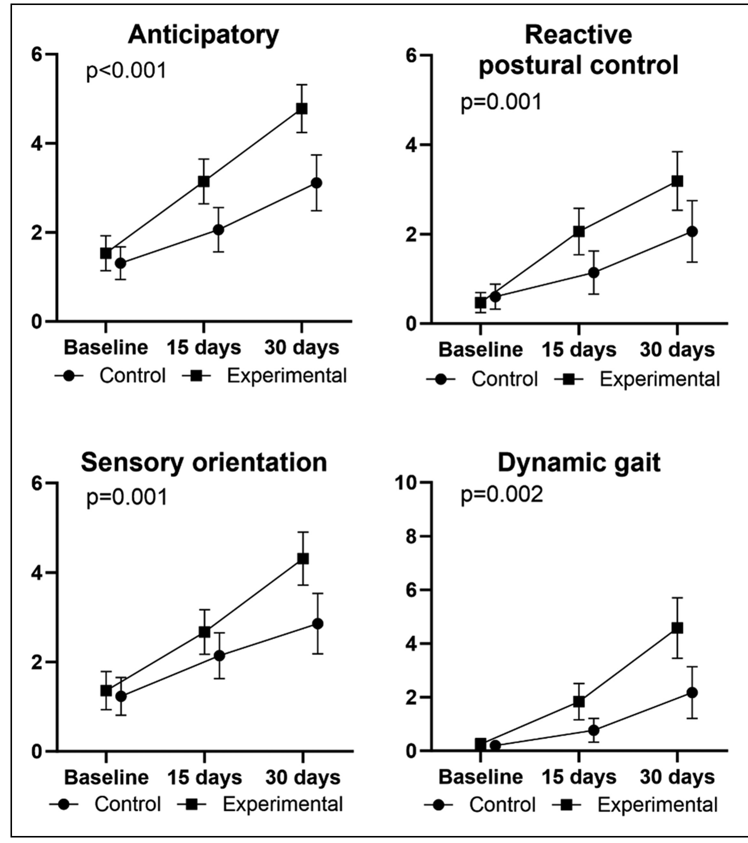

Figure 3. Changes over time on Mini BESTest subscales according to the treatment group. The *p*-value represents the time*group interaction after Greenhouse-Geisser correction.

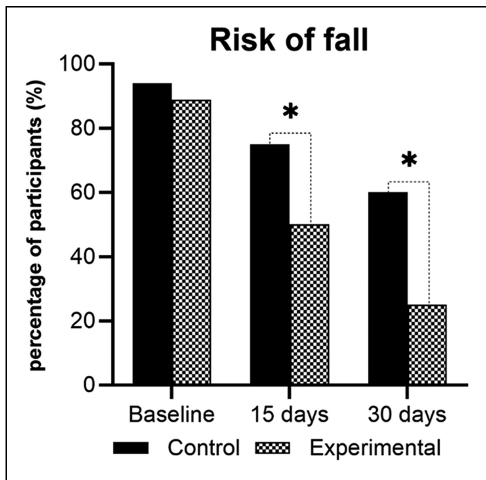

Figure 4. Frequencies of participants in risk of fall according to the Berg Balance Scale. * $p < 0.05$.

the balance training program appears to have a carry-over effect on functional gait, fall risk, and ADLs.

These results are in line with previous studies showing positive results in balance deficit in post-stroke patients after applying specific balance exercises.[31,32] However, most studies continue to exclude those with severe impairments, comorbidities, or older adults, limiting generalizability. Our findings address this gap, demonstrating that individuals over 65 with severe functional limitations can benefit from simple, easy-to-implement exercise programs within rehabilitation.

Specifically, we assessed balance using the Mini BESTest and BBS, with between-group analysis revealing significant improvements in the experimental group. Differences in all Mini BESTest subscales (Anticipation, Reactive Postural Control, Sensory Orientation, Dynamic Gait) were evident by 15 days, becoming clinically relevant by 30 days. These improvements likely stem from the balance program's comprehensive approach, targeting sensory, vestibular, and visual systems, as well as coordination. Exercises such as N1.3 and N1.4 (self-initiated stability) and N2.1 (externally provoked stability) helped improve postural control, a key challenge for older stroke survivors.[6]

The BBS score in the experimental group increased from 18.6 to 28.0 at 15 days, reflecting a 9-point improvement compared to 4.9 points in the control group. Previous studies suggest that an increase of 6.7 points in chronic stroke and 6.9 points in acute stroke is required for clinically significant changes in functional balance.[30,33] These results are notable, as improvements were evident not only at 30 days but also halfway through treatment (15 days), demonstrating that older adults can experience clinically meaningful changes in a short period. Such rapid improvements may boost motivation and treatment adherence.

At 30 days, the mean difference between groups exceeded the minimum detectable difference (5 points or 10%) in favor of the experimental group. A higher proportion of participants in the experimental group also reached the 31-point threshold, indicating a clinically significant reduction in fall risk. However, the BBS's accuracy in predicting falls is limited (<75%), and other factors such as medication and environmental conditions should also be considered.[34] This makes us think that it would have been valuable to also record extrinsic or environmental risk factors such as poor lighting and lack of safety equipment in the bathroom, among others.

Several factors contributed to the greater improvements in balance and fall risk in the experimental group. These patients engaged in more specific balance training, allowing for tailored tasks that addressed their individual deficits through a progressively challenging exercise program. This approach aligns with research suggesting that post-stroke rehabilitation for older adults should prioritize learning. We rely on the principle of "less is more." If individuals cannot sustain attention for long periods, they may not adequately process proprioceptive and other inputs necessary for relearning motor skills.[35] Secondly, the improvements in the experimental group could be attributed to the structure of the exercises. Level 1 of the program promotes procedural learning through automatic, repetitive tasks performed without conscious thought. Participants follow the physiotherapist's instructions and repeat movements slowly, which does not require awareness or attention—cognitive

processes often impaired in older post-stroke adults. In contrast, while progression to level 2 depends on mastering level 1, level 2 exercises demand more attention and awareness, utilizing declarative learning, which supports motor improvements in neurologically impaired patients.[35] Thirdly, the division of the program into difficulty levels based on learning principles likely contributed to the individualized nature of the exercise program, influencing the study's results. Fourthly, the inclusion of sensory integration exercises (tactile, kinesthetic, and vestibular stimulation) may further explain the experimental group's improvement. Aging and stroke often lead to sensory and musculoskeletal deficits, and post-stroke patients face an increased risk of sensory, motor, and cognitive impairments.[36] Regardless of the location or etiology of the stroke, there is often a period of inactivity after the stroke, with reduced mobility and fear of movement[37] which can affect sensory integration. Level 1 exercises, which focus on supine mobility and sensory integration in a safe environment, likely helped participants improve coordination of trunk and limb movements for balance activities such as sitting, standing, and functional movements like getting up or climbing steps.

The results also showed that improvements in balance had a positive effect on functional gait and autonomy of ADL. Increased balance control coincided with enhanced dynamic gait, though improvements in autonomy were not statistically significant. However, unlike other studies[4,5] that excluded patients with severe dependence, our study demonstrated that individuals in the experimental group progressed from severe to moderate dependence within just one month of intervention. These findings support the link between improved balance and greater autonomy, particularly in transfers and ambulation,[38,39] which are two situations of great risk of falls in older adults post-stroke.

There are several strengths in our study. First, the rigorous design ensures the validity of our findings. Second, follow-up assessments at 15 and 30 days allowed us to track the recovery timeline, revealing that our intervention accelerated the restoration of dynamic balance. This highlights how, with proper training, older adults can experience rapid recovery, potentially opening the door to early gait re-education. However, our study has some limitations. We did not measure walking speed, which would have enabled comparison with other studies. Additionally, we did not conduct long-term follow up to assess the persistence of improvements, nor did we collect data on quality of life, an important outcome for patients and caregivers. Assessing quality of life could have provided insight into the social impact of greater functional independence.

In conclusion, this study showed that a simple, easily reproducible approach designed by and for the older adult to rehabilitate post-stroke impairments was useful for improving their balance, functional gait, risk of falls, and ADLs. The implementation of this inexpensive, evidence-based program, which can be easily delivered by trained physical therapists, offers a comprehensive approach to rehabilitating impaired balance—one of the most restrictive deficits after stroke in older people.

Clinical messages

- Applying a simple rehabilitation approach tailored to older adults decreases balance deficits after stroke.
- The balance training program for older stroke patients offers opportunities for comprehensive rehabilitation and improved functional outcomes.
- The addition of a specific 15-minute older adult-tailored balance training program reduces the risk of falls and increases independence in ADLs among older adults after stroke.

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Author contributions

AM-R was involved in conceptualization, methodology, data curation, investigation, resources, project administration, and writing—original draft; LMP, CB-C, and AMB-F in conceptualization, methodology, and writing—review & editing; MAB in methodology and writing—review & editing; VD-G and AB-E in investigation and writing—review & editing; PB-L in formal analysis, investigation, data curation, visualization, and writing—original draft; and MG-F in conceptualization, methodology, investigation, resources, formal analysis, supervision, and writing—review & editing.

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Ethical statement

The project was approved by the Ethical Committee on Animal and Human Experimentation of the Universitat Autònoma de Barcelona and the Ethical Committee of the International University of Catalonia (VRIT-2017-03).

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Informed consent

Written informed consent was obtained from patients for their anonymized information to be published in this article and the consent has been obtained to display the face of the therapist in the photos provided.

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Supplemental material

Supplemental material for this article is available online.

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