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Title: The Effect of Frontal-Plane Balance Training on Fall Prevention in Chronic Stroke Survivors:
A Randomized Controlled Trial

Running Title: Lateral Balance Training to Prevent Falls

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Abstract:

Introduction: This study investigated the impact of frontal plane-focused balance training (FPBT) on fall prevention in stroke survivors.

Methods: 59 chronic stroke survivors (mean age: 52.24 ± 16.35 , 18 female) were divided into the FPBT and control group, both underwent an 8-week training program with three one-hour sessions weekly, incorporating single- and dual-task balance exercises. Primary outcomes included fall numbers and faller odds, while secondary outcomes assessed balance function using the Berg Balance Scale (BBS), Mini-Balance Evaluation Systems Test (Mini-BEST), Activities-Specific Balance Confidence Scale (ABC), and Fall Risk for Older People in the Community (FROP-Com).

Results: No statistically significant differences were found in fall numbers or faller odds between the groups during the training ($P=0.768$ and $P=0.065$) or follow-up period ($P=0.461$ and $P=0.298$), using Negative binomial and Logistic regression, respectively. A declining trend in fall risk was observed in the FPBT group compared to the control group. Both groups showed significant improvements in secondary outcomes (BBS: $P=0.013$, Mini-BEST: $P<0.001$, ABC: $P<0.001$, and FROP-Com: $P<0.001$), with no significant between-group differences (BBS: $P=0.395$, Mini-BEST: $P=0.295$, ABC: $P=0.186$, and FROP-Com: $P=0.886$).

Conclusion: The findings suggest that while FPBT did not significantly outperform conventional balance training in reducing falls, a trend toward fall risk reduction was observed. Further research is needed to optimize FPBT's effectiveness for stroke survivors.

The present study was registered in the Iranian Registry of Clinical Trials (No: IRCT20220703055350N1).

Keywords: balance, frontal plane focused balance training, stroke, fall

Highlights:

Investigating the effect of frontal-plane balance training on fall prevention in chronic stroke indicated that:

- FPBT showed consistent but non-significant reductions in fall numbers and faller odds compared to control across all periods, suggesting its potential as a promising intervention.
- All participants improved significantly in balance, mobility confidence, and fall risk measures post-intervention.
- No additional benefit of FPBT over control was found for any clinical outcome measure.
- Time effects dominated group effects, suggesting general benefits of any balance training.

Plain language summary:

This study tested whether a special type of balance training—focused on side-to-side (lateral) movements—could help prevent falls in people who have had a stroke. Falls are a major concern for stroke survivors, often leading to injuries and reduced independence. The researchers compared this new training, called Frontal-Plane Balance Training (FPBT), to traditional balance exercises to see if one worked better.

Fifty-nine stroke survivors were split into two groups: one did FPBT (practicing sideways balance exercises), while the other did standard balance training. Both groups exercised three times a week for eight weeks. The researchers tracked falls before, during, and six months after the training. They also measured balance, balance confidence, and fall risk using clinical tests.

- Both groups improved in balance and confidence, but FPBT wasn't significantly better than traditional training.
- FPBT showed a *trend* toward reducing falls—participants had fewer falls during and after training compared to the control group, but the difference wasn't large enough to be certain.
- No major differences were seen in balance test scores between the two groups, suggesting both methods helped similarly.

Falls after stroke can be life-changing, causing fractures or loss of independence. While FPBT didn't outperform standard training, the trend suggests it might still be helpful. The study also confirms that *any* balance training can improve stability and balance confidence for stroke survivors. Future research could explore whether longer or more intense FPBT programs make a bigger difference.

1. Introduction

The risk of falls and related injuries, such as fractures, is twice as high in stroke survivors compared to healthy individuals of the same age (Mansfield et al., 2017). While the majority of stroke survivors (approximately 75%) regain the ability to stand independently, they often experience balance disorders (de Haart et al., 2004; Mansfield et al., 2017). The decline in balance among post-stroke survivors critically affects their mobility and daily activities. This deterioration increases the risk of falls and limits social participation. Thus, assessing and rehabilitating balance, along with implementing fall prevention strategies, are essential priorities in their treatment. (An & Shaughnessy, 2011; Llorens et al., 2016; Charlotte SL Tsang et al., 2013).

Exercise can be employed either as a single preventive intervention or as part of a multifactorial program to reduce the incidence of falls among older adults (Low et al., 2017; Sherrington et al., 2017) and community-dwelling individuals with Parkinson's disease and cognitive impairments (Sherrington et al., 2017). However, there is still insufficient evidence to confirm the same for individuals who have suffered from a stroke (Lai et al., 2019; Sherrington et al., 2017). Failing to select the appropriate exercise therapy program could be one possible reason for inadequate results.

Previous research has demonstrated that after a stroke, balance impairments are more obvious in the frontal plane (de Haart et al., 2004; de Kam et al., 2018). Recent muscle synergy analysis has further revealed that deficits in muscle coordination are most pronounced during in-place postural responses, particularly when falling backward or toward the affected side (de Kam et al., 2018). Additionally, post-stroke survivors are more likely to fall toward the affected side or forward (F. A. Batchelor et al., 2012).

Given these findings, along with the established association between impaired lateral balance control and previous falls and risk of future and recurrent falls in stroke survivors (Hyndman et al., 2002; Maki et al., 2000), greater attention should be directed toward addressing lateral balance control disorders. Improving this balance aspect appears to be crucial for preventing falls in this vulnerable population.

Recent studies indicate that implementing DT training programs is promising for fall prevention in this population (Ahmed et al., 2021; Pang et al., 2018). However, Ahmed et al. (2021) highlighted the effect of multi-dimensional trunk movements and DT practices for stroke patients in enhancing trunk control and balance as well as reducing their risk of falling (Ahmed et al., 2021), but the role of improving lateral balance control in promoting functional balance, boosting balance confidence, and preventing falls remains overlooked.

The main purpose of this study was to investigate the impact of 'frontal plane-focused balance training' (FPBT) on functional balance control and the risk of falls in post-stroke individuals. It was hypothesized that: 1) FPBT would reduce the number of falls and the likelihood of being a faller compared to traditional balance training in the post-stroke population, and 2) the FPBT group would show more significant improvement in functional balance control than the control group.

2. Materials and Methods

2.1. Participants

The University of Social Welfare and Rehabilitation Sciences Ethics Committee approved this study (Approval No: IR.USWR.REC.1398,136). The present study was registered in the Iranian Registry of Clinical Trials (No: IRCT20220703055350N1). Every participant signed an informed consent form before participating in the survey. This double-blinded, randomized

controlled trial was conducted at the Balance Laboratory of the Mashhad University of Medical Sciences Research Center between February 2020 and December 2023. Due to the COVID-19 pandemic, the evaluation process was halted for approximately two years during the outbreak's peak and quarantine.

Community-dwelling adults with chronic stroke (>6 months post-stroke) were recruited from clinics in Mashhad. Volunteers conducted telephone screenings and attended an initial assessment where written informed consent was obtained and eligibility confirmed. Common inclusion criteria were: 1) the ability to stand and walk independently for one minute, 2) no recent limb surgery, and 3) no uncorrected visual or auditory impairments. Exclusion criteria were: 1) a score higher than 2 on the Modified Ashworth Scale for calf muscle spasticity (Li et al., 2014), 2) a score lower than 24 on the Persian version of the Mini-Mental State Examination (Ansari et al., 2010) to verify the lack of serious cognitive issues, 3) a standard deviation of ± 1 or greater on the Line Bisection Test (indicating a history of hemineglect) (Plummer et al., 2003), or 4) any balance-affecting conditions other than stroke. Based on the pilot study, the sample size was determined using the following values:

The standard deviation (σ) was 0.23, while the difference in means (d) was 0.21. The significance level was set at 0.05, and the desired statistical power was set at 0.84. After accounting for an attrition rate of 10%, the total sample size required was 23 participants in each group.

2.2 Randomization:

An independent research assistant conducted the randomization process, assigning participants to blocks of four using specialized software. This resulted in 25 patients in the FPBT group and 25 in the control group, which received traditional balance training.

2.3 Blinding:

Both the assessors and participants were unaware of the group assignments. The physiotherapist (MP) was blinded by the balance assessment results as well.

2.4. Primary outcome: Falls

A fall was ‘an event that results in a person coming to rest unintentionally on the ground or other lower level’ (Hyndman et al., 2002). Participants completed a fall reporting process a year before the 8-week balance training, during the training period, and 6 months afterward. A research assistant called participants monthly to check for falls, and those who reported a fall completed a brief questionnaire about the cause, circumstances, and consequences.

2.5. Secondary Outcomes

Demographic data were collected from participants. They were also assessed by the Berg Balance Scale (**BBS**) (Salavati et al., 2012) and the Mini-Balance Evaluation System Test (**Mini-BEST**) (Molhemi et al., 2024), which evaluated their dynamic functional balance control. BBS is a reliable 14-item balance assessment tool for stroke patients, graded on a 5-point scale, with a total score from 0 to 56. It shows high inter-rater reliability (ICC: 0.98) and intra-rater reliability (ICC: 0.97) in this population (Berg et al., 1995). Mini-BEST, another dynamic balance assessment with 14 items, boasts excellent reliability (intra-rater ICC: 0.97, inter-rater ICC: 0.96), graded on a 3-point scale, scoring from 0 to 28 (C. S. Tsang et al., 2013). The Activities-Specific Balance Confidence (**ABC**) Scale assesses the psychological impact of balance impairments (Hassan et al., 2015) with strong reliability (internal consistency: 0.94, test-retest ICC: 0.85), scoring confidence from 0% to 100%. The percentage for each of the 16 items is averaged (Botner et al., 2005). The Fall Risk for

Older People in the Community (**FROP-Com**) screening tool is a 28-item screening tool evaluating fall risk factors with high reliability (intra-rater ICC: 0.93, inter-rater ICC: 0.81). A score of 19 or higher post-rehabilitation indicates a high fall risk, making individuals 4.5 times more likely to fall in the following year compared to those scoring below 19 (Man-Di Ng et al., 2017; Russell et al., 2008).

2.6. Intervention:

Participants underwent an 8-week program with three 60-minute weekly sessions. Each session included a 10-minute warm-up and five balance exercises, each done for ten repetitions. In total, participants engaged in between 20 to 24 treatment sessions. All training sessions were scheduled in the morning. The FPBT group participated in a training program focused on balance in the frontal plane, while the control group engaged in traditional balance exercises (see the Appendix). The training began with static exercises, progressing to dynamic ones in single and dual-task conditions. Single-task exercises were initially introduced, followed by motor dual-task exercises, and then cognitive dual-task conditions were added. This approach accounts for the complexities introduced by combining speech production with movement, which can negatively impact groups susceptible to falls (Ghai et al., 2017). Consequently, cognitive exercises were included only in the final stages.

The priority of concurrent tasks varied during the exercises, with participants focusing on either the primary balance or the secondary motor/cognitive task. In variable-priority conditions, attention shifted between tasks, while in fixed-priority conditions, it was evenly split. Variable-priority conditions have shown benefits over fixed-priority ones (Ghai et al., 2017; Silsupadol et al., 2009).

The motor secondary tasks included carrying a cup of water, holding a ball in the hand, and carrying a shopping bag with an uninvolved hand. The cognitive secondary tasks include: naming as many animals as possible during the exercise time (subdomain of fluency), reciting the first 20 letters of the alphabet, counting from 1 to 20, and finally combining these two in an alternating manner (e.g., 1-A, 2-B, 3-C, etc.) (subdomain of mental Alternation Test), naming words that begin with a specific letter, such as "P" (subdomain of Controlled Oral Word Association Test), all of these tasks are categorized under of the “executive domain” (Tuokko et al., 2017).

Post-test assessments were carried out between 7 and 10 days after treatment completion, while follow-up assessments occurred 6 months later.

2.7. Statistical Analysis

Data analysis was conducted using SPSS version 21. The Independent t-test, Mann-Whitney U, and Chi-square test were employed to compare the two groups regarding demographic data. Fall numbers and the proportion of fallers were used to compare falls between the two groups. Logistic regression was employed to compare the proportion of fallers, while negative binomial regression was used to analyze the number of falls between the FPBT and control groups. The One-way repeated measure ANOVA was employed to compare BBS, Mini-Best, ABC, and FROP-Com scores within and between groups. The statistical significance level was $\alpha=0.05$.

3. Results

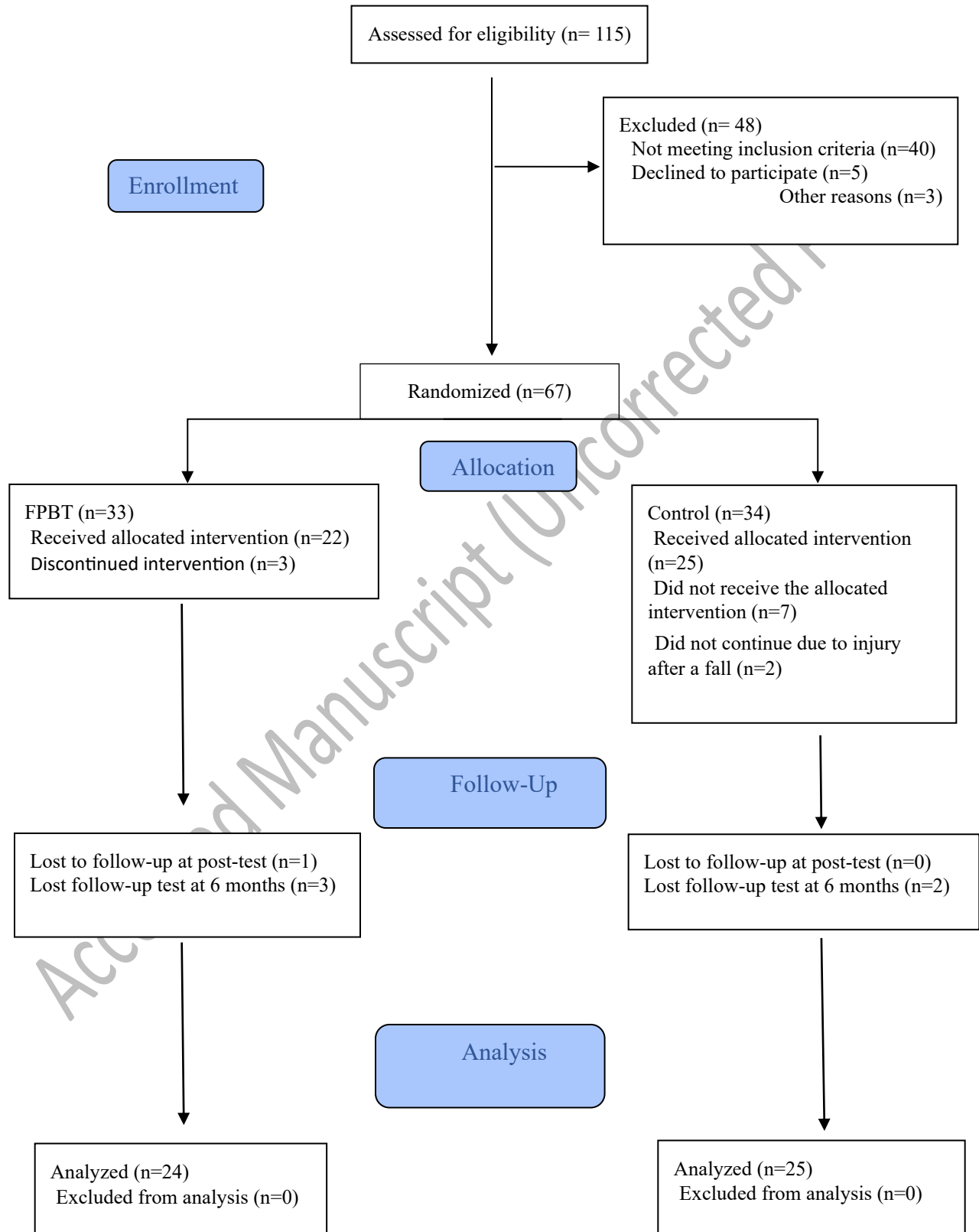
3.1. Recruitment

We screened 115 participants, of which 40 did not meet the criteria, 5 opted out of training, and 3 had other reasons. Sixty-seven were assigned to groups: 34 in the control and 33 in the FPBT

group. In the control group, 9 withdrew (7 did not complete, 2 were injured after a fall). In the FPBT group, 8 chose not to continue. After the intervention, 1 in FPBT and 2 in the control group missed the follow-up assessment. Ultimately, 59 participants were included in the analysis: 24 from FPBT and 25 from the control group (Figure 1).

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Figure 1: Fellow chart of the study.



3.2. Demographic data

Both groups had similar baseline characteristics, except for the type of stroke, where there were more ischemic stroke patients in the control group than in FPBT ($P=0.04$) (Table 1).

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Table 1: Demographic characteristics in both groups

Variable	Group		P-value
	FPBT(N=24) Mean (SD)	Control (N=25) Mean (SD)	
Age (years)	49.92 (16.46)	54.56 (16.24)	0.33**
Height (cm)	167.54 (9.90)	168.00 (11.29)	0.88*
Weight (kg)	70.81 (17.37)	71.60 (11.42)	0.85*
Body Mass Index (kg/m ²)	25.04 (4.91)	25.57 (4.50)	0.49**
Sex (No., %)			
Female	11 (45.8)	7 (28.0%)	0.20***
Male	13 (54.2)	18 (72.0%)	
Time since stroke (months)	22.25 (17.43)	23.56 (18.98)	0.71**
Education (No., %)			
Elementary or lower	9 (37.5%)	10 (40.0%)	0.98***
Diploma or associate degree	9 (37.5%)	9 (36.0%)	
Bachelor's or higher	6 (25.0%)	6 (24.0%)	
Dominant side (No., %)			
Right	22 (91.7%)	24 (96.0%)	0.53***
Left	2 (8.3%)	1 (4.0%)	
Paretic side (No., %)			
Right	8 (33.3%)	11 (44.0%)	0.41***
Left	16 (66.7%)	14 (56.0%)	
Type of stroke			
Ischemic	8 (33.3%)	16 (64.0%)	0.04***
Hemorrhagic	8 (33.3%)	7 (28.0%)	
Unknown	8 (33.3%)	2 (8.0%)	

SD: Standard Deviation

**Mann-Whitney

*Independent T-test

*Chi-Square test

3.3. Primary outcome: Fall

Tables 2, 3, and 4 show the number of falls, fall ratios, Exponential β [Exp. (β)] indicating the average of fall numbers, faller numbers, faller odds, Odds Ratio (OR), , and comparison between the two groups in the year before, during, and the 6-month follow-up period. During the year leading up to the training, fall history was recorded. There were 45 falls in the FPBT group and 29 falls in the control group. A negative binomial regression analysis indicated no significant difference in the number of falls between the two groups ($P = 0.39$). Before the start of the training, participants in the FPBT group experienced 39% more falls than those in the control group. There were 16 fallers in the FPBT group and 14 in the control group. A Logistic regression analysis indicated that the difference in faller odds between the two groups was insignificant (OR: 1.91 (0.58-6.23); p-value: 0.28). Prior to the training program, the odds of being a faller were 91% higher in the FPBT group compared to the control group (Table 2).

Table 2: Numbers of Falls and Faller Odds in both groups, a year before the training.

Group	Falls No.	Falls No. Ratio	Exp.(β) 95% CI	P-value	Faller No.	Faller Odds	Exp. (β) (OR) 95%CI	P-value
FPBT (N=23)	45	1.96	1.39 (0.66-2.92)	0.390	16	2.28	1.91 (0.58-6.23)	0.284
Control (N=25)	29	1.16	1		14	1.27	1	

OR: odds ratio, CI: confidence interval, Exp. (β): Exponential β .

During the training, 16 falls were recorded among 8 individuals in the FPBT group, compared to 19 falls among 15 individuals in the control group. However, the differences between the two groups regarding the number of falls and the faller odds were not statistically significant (Exp.(β): 0.88 (0.37- 2.09) and OR: 0.33 (0.10-1.07), $P = 0.768$ and 0.065 , respectively). Notably, the number of falls and the faller odds decreased by 12% and 67%, respectively, in the FPBT group compared to the control group during the training (Table 3).

Table 3: Numbers of Falls and Faller Odds in both groups during the training

Group	Falls No.	Falls No. Ratio	Exp. (β) 95% CI	P-value	Faller No.	Faller Odds	Exp. (β) (OR)	P-value 95%CI
FPBT (N=24)	16	0.69	0.88 (0.37- 2.09)	0.768	8	0.50	0.33 (0.10-1.07)	0.065
Control (N=25)	19	0.76	1		15	1.50	1	

OR: odds ratio, CI: confidence interval, Exp. (β): Exponential β .

There were 13 falls in FPBT versus 19 in the control group during the 6-month follow-up period. The fallers were 8 in FPBT versus 12 in the control group. The difference in fall number was insignificant between the two groups (Exp.(B): 0.71 (0.29- 1.75); P=0.461), similar to faller odds (OR:0.54 (0.1-1.72); P = 0.298). The number of falls and faller odds in FPBT were 29% and 46% lower than the control group during the 6-month follow-up, respectively (Table 4).

Table 4: Numbers of Falls and Faller Odds in both groups during follow-up

Group	Falls No.	Falls No. Ratio	Exp. (β) 95% CI	P-value	Faller No.	Faller Odds	Exp. (β) (OR)	P-value 95%CI
FBPT (N:24)	13	0.54	0.71 (0.29- 1.75)	0.461	8	0.50	0.54 (0.17-1.72)	0.298
Control (N:25)	19	0.76	1		12	0.92	1	

OR: odds ratio, CI: confidence interval, Exp. (β): Exponential β .

Although the differences in the number of falls and the odds of being a faller between the two groups were not statistically significant during the training and follow-up periods, a decreasing trend was observed in the FBPT group compared to the control group when considering the data before the training began.

3.4. Secondary outcomes: Clinical Tests

3.4.1. BBS Score

A one-way repeated measures ANOVA analysis revealed that the interaction between time and group was insignificant ($P = 0.833$) in the BBS scores. Additionally, the main effect of the group was also not significant ($P = 0.395$). However, the main effect of time was significant ($P = 0.013$). This indicates that BBS scores showed a statistically significant improvement after the training period in both groups. A significant difference was found between the pre-training assessment and the follow-up ($P = 0.007$) (see Table 5).

Table 5: Repeated Measures Analysis of Within-Group Differences

Scale/ Questionnaire	Time (Main effect) P-value	Pre Mean (SD)	Post Mean (SD)	Follow- up Mean (SD)	Pre vs. Post P-value (95%CI)	Post vs. follow-up P-value (95%CI)	Pre vs. follow- up P-value (95%CI)
BBS	0.013	47.04 (7.92)	49.26 (9.57)	50.21 (6.36)	0.093 (-4.68- 0.26)	1.000 (-3.99-2.08)	0.007 (-5.62- -0.72)
Mini-BEST	0.000	15.96 (6.31)	20.84 (7.08)	19.75 (4.95)	<0.001 (-7.24- -2.53)	0.585 (-0.99-3.21)	<0.001 (-5.63- -1.93)
ABC	0.000	61.18 (21.26)	71.40 (20.12)	76.26 (15.12)	0.001 (-16.69- -3.83)	0.238 (-11.62-1.87)	<0.001 (-21.91- -8.34)
FROP-Com	0.000	14.18 (6.59)	11.61 (5.80)	11.22 (5.32)	0.001 (0.87-4.32)	0.585 (-0.99-3.21)	0.002 (0.99-4.94)

SD: standard deviation, CI: confidence interval, BBS: Berg Balance Scale, Mini-BEST: Mini Balance Evaluation System Test,

ABC: Activities-Specific Balance Confidence, FROP-Com: Fall Risk for Older People in the Community.

3.4.2. Mini-BEST Score

The interaction effect of time and group on Mini-BEST scores was found to be insignificant ($P = 0.314$). Likewise, the main effect of the group did not demonstrate significance ($P = 0.295$). However, the main effect of time was significant ($P \leq 0.001$). This indicates that, irrespective of the group, there was a statistically significant difference in Mini-BEST scores after the training period. Table 5 illustrates a significant difference between the pre-training assessment and the post-assessment ($P \leq 0.001$), as well as between the pre-assessment and the 6-month follow-up assessment ($P \leq 0.001$).

3.4.3. ABC Score

The interaction effect of time within the group was not significant ($P = 0.657$). As well, the main effect of the group also did not reach significance ($P = 0.186$). However, the main effect of time was significant ($P < 0.001$). This indicates that, regardless of group membership, ABC scores demonstrated a statistically significant difference after the training. According to Table 5, significant differences were observed between the pre-training assessment and the post-assessment ($P < 0.001$), as well as between the pre-assessment and the follow-up results ($P < 0.001$).

3.4.4. FROP-Com Scores

In the FROP-Com test scores, the interaction effect of time within the group was not significant ($P = 0.250$). Moreover, the main effect of the group was also not significant ($P = 0.886$). However, the main effect of time was found to be significant ($P < 0.001$). The FROP-Com scores indicated a statistically significant difference following balance training. There was a significant difference between the pre-training assessment and the post-assessment ($P = 0.001$), as well as between the pre-assessment and the follow-up assessment ($P = 0.002$) (Table 5).

Insert Table 3 near here, please.

3.5. Harms and Fall-related Injuries:

During the training period, 11 adverse events occurred following a fall in both groups. There were 7 bruises (5 in FPBT and 2 in the control group), 2 fractures (both participants were in the control group and were withdrawn from the study), and one cut (an FPBT participant). One FPBT

participant with a history of frequent seizures experienced a seizure following the training session. One control participant experienced high blood pressure following the training which was controlled after a rest.

14 fall-related injuries occurred during the follow-up period. There were 9 bruises (all in the control group), 3 fractures (2 FBPT participants and one control participant), and 2 cuts (both in FPBT).

4. Discussion

4.1. falls

This study examined how frontal plane-focused balance training affects functional balance control, balance confidence, and fall risk in individuals who have experienced a stroke. There was no statistically significant difference between the two groups in the number of falls and odds of being a faller at the baseline (P : 0.39 and 0.28, respectively). Previous studies have indicated a link between falls and lateral balance (de Haart et al., 2004; Maki et al., 1994; Melzer et al., 2004; Stel et al., 2003), leading to the hypothesis that balance exercises targeting the frontal plane could help prevent falls in stroke patients. However, the results did not support this hypothesis.

The results showed that neither the number of falls during the follow-up period (Exp(B) : 0.71; 95% CI: 0.29-1.75, P = 0.461) nor the odds of being a faller (OR : 0.54; 95% CI: 0.17-1.72, P = 0.36) differed significantly between the two groups. Notably, 6 months after the training, the number of falls in the control group was 29% higher, and the odds of being a faller were 46% higher compared to the FPBT group. Similarly, the differences in the number of falls and faller odds did not show statistical significance during the training period (Exp(B) : 0.71; 0.88; 95% CI: 0.37-2.09, P = 0.768 and OR : 0.54; 95% CI: 0.1-1.72, P = 0.362, respectively). Interestingly, the FPBT group experienced a reduction of 12% in the number of falls and a 67% decrease in the odds

of being a faller compared to the control group during this period. Given the higher baseline measurements observed in the FPBT group—showing a 39% increase in the number of falls and a 91% increase in the odds of being a faller compared to the control group—a trend towards a decreased risk of falls was noted both during and after the training period. Although the results did not establish a significant difference between the two groups in fall-related variables, the observed declining trend suggests the potential efficacy of the FPBT program.

Peng et al. (2018) found that 60 minutes of dual-task balance and mobility exercises, three times a week for eight weeks, reduced falls and injuries in stroke patients during a 6-month follow-up compared to single-task exercises ($P < 0.037$). (Pang et al., 2018). Similarly, Ahmad et al. (2021) reported that a high-intensity, multi-planar trunk exercise regimen in a dual-task context for 45 minutes, five times a week for three months, significantly decreased the risk of falls at 6 and 12 months, benefiting trunk control in patients (Ahmed et al., 2021). One possible reason for the lack of a significant difference in fall risk between the two groups could be that participants in the control group also performed dual-task exercises. It remains unclear whether dual-task conditions or the direction of the exercises—lateral or diagonal—are more critical in preventing falls.

Moreover, the length of the training period is also in question. Pang et al. used the same duration as we did, finding a significant reduction in fall risk in the DT group (Pang et al., 2018). In contrast, Ahmed et al. achieved similar results with a longer duration, emphasizing that conventional exercises typically involve only 23 sessions in three months, whereas this should be increased to 60–70 sessions per patient (Ahmed et al., 2021).

A review of the literature shows that therapeutic exercises have generally not been effective in preventing falls in stroke patients (Batchelor et al., 2010; Mansfield et al., 2018; Verheyden et al., 2013; Winser et al., 2018). Most studies concentrated on single interventions that may be effective

for non-stroke populations but not for strokes (Batchelor et al., 2010; Lai et al., 2019; Yang et al., 2021). Contributing factors include varying intervention types, inconsistent measurement criteria, differing definitions of falls, fall reporting methods, inadequate focus on falls as a primary outcome, and insufficient intensity or volume of exercises (Batchelor et al., 2010; Yang et al., 2021).

Some studies used multifactorial approaches combining therapeutic exercises and fall prevention recommendations, but even these trials failed to reduce fall rates among stroke patients (Frances A Batchelor et al., 2012; Dean et al., 2012; La Porta et al., 2022). Nevertheless, A recent systematic review highlighted that effective fall-prevention interventions involve multifactorial programs targeting multiple risk factors, ensuring adequate exercise volume and intensity, adopting consistent definitions and tracking for falls, and maintaining sustainable methodologies (Yang et al., 2021). Further investigations would confidently establish that implementing dynamic balance and mobility exercises in the lateral direction as a single intervention effectively prevents falls in the post-stroke population.

4.2. Clinical tests

Researchers hypothesize that BBS and Mini-BEST scores would significantly differ between the various measurement sessions within and between the two groups. Based on the results, a significant within-group difference was observed between the measurement sessions in both groups, confirming the researcher's hypothesis ($P = 0.013$ and $P < 0.001$, respectively). However, no significant difference in the scores of the BBS and Mini-BEST was observed between the two groups ($P = 0.395$ and $P = 0.295$, respectively).

Although BBS scores increased after treatment, no significant improvement in functional balance was seen in either group (Table 5). However, follow-up scores significantly increased from baseline ($P = 0.007$). Participants initially had a good balance level (BBS score: 47.04 ± 7.92), which may explain the lack of immediate change.

Improvements in balance following training are influenced by the initial level of instability (Yang et al., 2011). Individuals who have experienced a stroke tend to exhibit greater instability in the mediolateral direction. (de Haart et al., 2004; de Kam et al., 2018; Yang et al., 2011). De Haart et al. (2004) found that immediately following 12 weeks of balance training, there was greater improvement in frontal plane balance compared to sagittal plane balance (de Haart et al., 2004). Thus, the delayed improvement in sagittal plane balance during the follow-up session may have contributed to the notable enhancements in clinical balance (BBS scores) observed.

On the other hand, these results may indicate that BBS has limited sensitivity in detecting changes in balance in the frontal plane, while the improvement could be seen in the results of the Mini-BEST test (Table 5). Previous studies that examined the correlation between the center of pressure parameters or stability indices and the BBS scores have confirmed either no correlation (Cho et al., 2014; Sawacha et al., 2013) or a weak correlation (Parsa et al., 2019) between these variables in the medial-lateral direction and the BBS score.

The Mini-BEST assessments showed a significant difference in post-treatment evaluations ($P = 0.000$). Despite a slight decline in Mini-BEST scores during follow-up (from 20.84 to 19.75), the treatment effect was still significant compared to baseline ($P = 0.000$). Mansfield et al. (2018) found no significant differences between intervention and control groups after 6 weeks of perturbation-based balance training or 6-month follow-up, though a borderline difference was observed at the 12-month follow-up ($P = 0.049$) (Mansfield et al., 2018). Their training plan

primarily focused on improving reactive balance, resulting in negligible outcomes in Mini-BEST scores as a measure of functional balance.

ABC and FROP-Com scores indicated significant within-group differences ($P < 0.001$). However, the between-group difference did not reach a significant level ($P = 0.186$ and $P = 0.886$, respectively). Balance training improved confidence and reduced fall risk, according to ABC and FROP-Com results. The positive effects persisted after 6 months, with significant score differences ($P < 0.001$ and $P = 0.002$, respectively), indicating that engaging in conventional exercise may also be beneficial.

Increased balance confidence following various types of balance training has been demonstrated in previous studies (Mansfield et al., 2018; Pang et al., 2018). These results indicate that balance rehabilitation has lasting psychological effects, enhancing self-efficacy and balance confidence. Studies show that 50 to 60 percent of individuals experience a loss of balance confidence (Myers et al., 1996), rising to 88% among those who have fallen (Schinkel-Ivy et al., 2016). Improved balance confidence can boost motivation to walk and engage in activities but may also lead to overconfidence and risk acceptance, signaling progress toward greater independence (Mansfield et al., 2018).

It appears that balance training, regardless of its type, has been effective in influencing various domains such as balance, gait, physical activity, functional behavior in daily activities, and to some extent, cognitive status. Therefore, improvements were observed in both groups following the therapeutic intervention, but no difference was seen between the two groups. Shaw et al. (2017) in a review study showed that balance and mobility, use of sedatives and psychotropic drugs, and inability to self-care are strongly correlated with falls in community-dwelling stroke patients, while depression, cognitive impairment, and a history of falls show moderate correlation [115]. The

author notes that all the risk factors identified in stroke patients, except for depression, are included in the FROP-Com questionnaire. Although the scores of this questionnaire in both groups were around 14 at the initial assessment (below the threshold of 19, which indicates a low risk of falling), a reduction of approximately 2.5 points and its persistence after 6 months may indicate the promising effect of balance training in improving the functional status of individuals. Previous studies investigating the effects of multifactorial fall prevention programs in stroke patients have reported mixed results in FROP-Com scores following therapeutic interventions [9, 117].

Shaw et al. (2017) found that balance, mobility, and use of sedatives are strongly correlated with falls in community-dwelling stroke patients, while depression and cognitive impairment show a moderate correlation (Xu et al., 2018). The FROP-Com initial scores were around 14 (below the fall risk cut-off:19), and a reduction of about 2.5 points was sustained after 6 months, suggesting the positive effects of balance training. Previous studies on multifactorial fall prevention in stroke patients have shown mixed results regarding FROP-Com scores (F. A. Batchelor et al., 2012).

5. Conclusion:

This study explored the efficacy of FPBT in enhancing functional balance control and balance confidence and reducing fall risk among chronic stroke survivors. Although no statistically significant differences were observed between the FPBT and conventional balance training groups regarding fall rates or faller odds, both interventions demonstrated significant improvements in functional balance, balance confidence, and fall risk reduction over time. The declining trend in fall risk observed in the FPBT group suggests its potential as a promising intervention, warranting further investigation with larger sample sizes, longer training durations, and adding another group performing FPBT in a single-task context.

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Conflict of Interests

None of the authors has any financial or other interests related to the manuscript to declare.

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Authors' contributions:

MP, MAS, HN, and IA contributed to the conception, methodology, design of the study, interpretation of data, and drafting or substantial revision of the work. MP, HFH, and MR contributed to the acquisition of data. MP and EB contributed to the statistical analysis of data. MP, MAS, and HN have drafted and revised the final manuscript. All authors have approved the submitted version.

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Appendix

FPBT Group Exercises

Static Exercises

- Semi-Tandem Standing
(If possible, foot positioning was altered during repetitions. Otherwise, the affected foot was placed forward.)
- Single-Leg Standing
(Priority was given to the unaffected leg. For most patients, a 10-cm step was placed under the raised foot. To increase difficulty, the support surface on the step was reduced.)
- Reaching Right and Left
(Aimed at challenging balance more in the medial-lateral direction.)
- Forward Half-Lunge
(Reducing the support surface in the medial-lateral plane to challenge balance in this plane.)
- Applying External Perturbations (30 seconds sideways by the therapist)

Dynamic Exercises

- Walking while crossing obstacles
- Sideways walking
- Alternating forward and backward half-lunge with both legs
(dynamic half-lunge followed by returning to the starting position.)
- Stair climbing
(5 repetitions forward, 5 repetitions sideways.)
- Semi-tandem walking

*Dynamic exercises were performed over a 3-meter distance with 10 repetitions.

Control Group Exercises

Static Exercises

- Standing with feet together
- Standing while gazing forward with torso rotation and head rotation
- Hand Reaching Forward and Upward
- Standing on Tiptoes
- Applying External Perturbations (30 seconds forward/backward)

Dynamic Exercises

- Walking Backward
- Alternating Side Steps (Left and Right) with Both Legs
- Walking and Moving Around Obstacles
- Stair Climbing (Forward Only)
- Walking While Rotating the Head Side to Side

Exercise Progression Guidelines

- Support Surface: Large to Small
- Upper Limb Support: Use arms for support to perform movements without support
- External Support: Use a wall or railing to perform movements independently
- Visual Condition: Eyes open to eyes closed
- Surface Stability: Firm surface to soft surface
- Single-Leg Standing Progression:

Start with the raised foot on a step, gradually reduce the support surface, and eventually remove weight from the non-supporting leg completely.

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