Research Paper

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

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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: A total of 59 chronic stroke survivors (mean age: 52.24±16.35 y, 18 female) were divided into the FPBT and control groups; both underwent an 8-week training program with three 1-hour sessions per week, 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 decline in fall risk was observed in the FPBT group compared with 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.

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Highlights

- FPBT showed consistent, though 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 after the intervention.

- No additional benefit of FPBT over control was found for any clinical outcome measure.

- Time effect dominated group effect, 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), with traditional balance exercises to see which 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 the practice three times a week for 8 weeks. The researchers tracked falls before, during, and 6 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 did not differ significantly from traditional training. PBT showed a trend toward reducing falls: participants had fewer falls during and after training compared to the control group, but the difference was not 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 a stroke can be life-changing, causing fractures or loss of independence. While FPBT did not 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 examine whether longer or more intensive FPBT programs make a greater difference.

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; 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 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 (Batchelor et al., 2012b).

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 crucial for preventing falls among this vulnerable population.

Recent studies indicate that implementing dual-task (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. Still, 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.

Materials and Methods

Study participants

The University of Social Welfare and Rehabilitation Sciences Ethics Committee approved this study. The present study was registered in the Iranian Registry of Clinical Trials (IRCT). 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 2 years during the outbreak's peak and the quarantine period.

Community-dwelling adults with chronic stroke (>6 months post-stroke) were recruited from clinics in Mashhad City, Iran. Volunteers conducted telephone screenings and attended an initial assessment, during which written informed consent was obtained and eligibility confirmed. Common inclusion criteria were as follows: 1) the ability to stand and walk independently for one minute, 2) no recent limb surgery, and 3) no uncorrected visual or auditory impairments. The exclusion criteria were as follows: 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 a 10% attrition rate, the total sample size required was 23 participants per group.

Randomization

An independent research assistant conducted the randomization process, assigning participants to blocks of 4 using specialized software. This estimation resulted in 25 patients in the FPBT group and 25 in the control group receiving traditional balance training.

Blinding

Both the assessors and participants were unaware of the group assignments. The physiotherapist (Mitra Parsa) was also blinded to the balance assessment results.

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.

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 (intraclass correlation coefficient [ICC: 0.98]) 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 (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 re-test ICC: 0.85) and scores 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 instrument 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 than those with a score below 19 (Man-Di Ng et al., 2017; Russell et al., 2008).

Intervention

Participants underwent an 8-week program with three 60-minute weekly sessions. Each session included a 10-minute warm-up and 5 balance exercises, each done for 10 repetitions. In total, participants engaged in 20-24 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 affect groups at risk of 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 conducted between 7 and 10 days after treatment completion, and follow-up assessments were conducted 6 months later.

Statistical analysis

Data analysis was conducted using SPSS software, version 21. The independent t-test, Mann-Whitney U test, and chi-square test were employed to compare the two groups on demographic data. Fall numbers and the proportion of fallers were used to compare falls between the two groups. Logistic regression was used to compare fall rates, and negative binomial regression was used to analyze fall counts between the FPBT and control groups. A one-way repeated-measures ANOVA was employed to compare BBS, Mini-Best, ABC, and FROP-Com scores within and between groups. The statistical significance level was set at 0.05.

Results

Recruitment

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

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).

Primary outcome: Fall

Tables 2, 3, and 4 show the number of falls, fall ratios, and 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

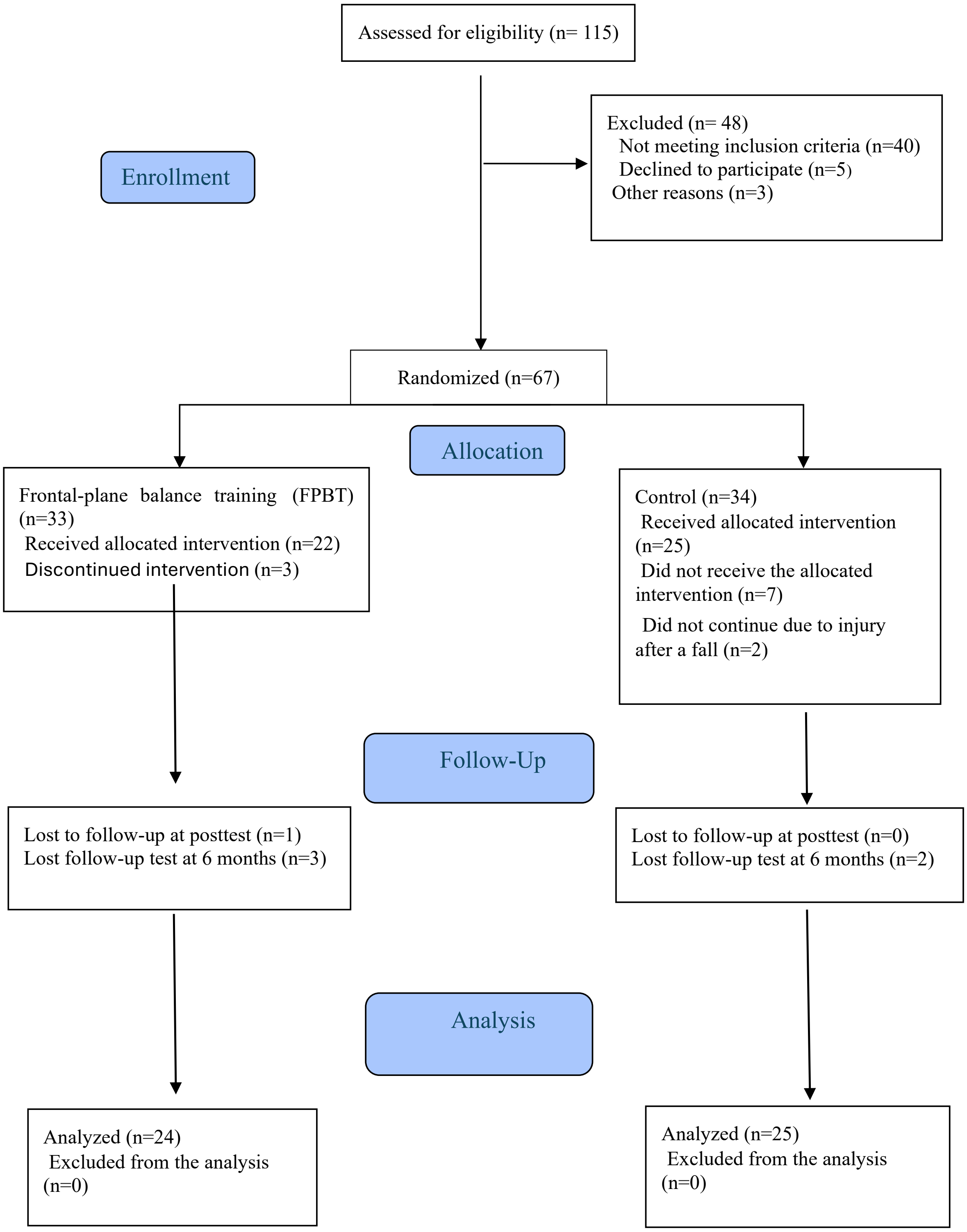

Figure 1. The study flowchart

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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 in-

Table 1. Demographic characteristics in both groups

Variables		Mean±SD/No. (%) Group: Frontal-plane Balance Training (FPBT) (n=24)	Mean±SD/No. (%) Group: Control (n=25)	P
Age (y)		49.92±16.46	54.56±16.24	0.33**
Height (cm)		167.54±9.9	168±11.29	0.88*
Weight (kg)		70.81±17.37	71.6±11.42	0.85*
Body mass index (kg/m²)		25.04±4.91	25.57±4.5	0.49**
Sex	Female Male	11(45.8) 13(54.2)	7(28) 18(72)	0.20***
Time since stroke (m)		22.25±17.43	23.56±18.98	0.71**
Education	Elementary or lower Diploma or associate degree Bachelor's or higher	9(37.5) 9(37.5) 6(25)	10(40) 9(36) 6(24)	0.98***
Dominant side	Right Left	22(91.7) 2(8.3)	24(96) 1(4)	0.53***
Paretic side	Right Left	8(33.3) 16(66.7)	11(44) 14(56)	0.41***
Type of stroke	Ischemic Hemorrhagic Unknown	8(33.3) 8(33.3) 8(33.3)	16(64) 7(28) 2(8)	0.04***

**The Mann-Whitney test, *The Independent t-test, ***The chi-square test.

dicated that the difference in fall odds between the two groups was insignificant (OR: 1.91 [0.58-6.23]; P: 0.28). Before the training program, the odds of being a faller were 91% higher in the FPBT group compared to the control group (Table 2).

During training, 16 falls were recorded among 8 individuals in the FPBT group, compared with 19 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).

There were 13 falls in the 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 not significant 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 those of the control group during the 6-month follow-up, respectively (Table 4).

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 in the data collected before the training began.

Secondary outcomes: Clinical tests

BBS score

A one-way repeated-measures ANOVA revealed that the interaction between time and group was not significant (P=0.833) for 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 result indicates that BBS scores improved significantly after the training period in both groups. A significant difference was found between the pre-training assessment and the follow-up (P=0.007) (Table 5).

Mini-BEST score

The interaction between time and group on Mini-BEST scores was not significant (P=0.314). Likewise,

Table 2. Numbers of falls and faller odds in both groups, 1 year before the training

Group	Falls No.	Falls No. Ratio	Exp.(β) 95% CI	P	Faller No.	Faller Odds	Exp. (β) (OR) 95% CI	P
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	

Abbreviations: OR: Odds ratio; CI: Confidence interval; Exp. (β): Exponential β.

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the main effect of the group did not demonstrate significance (P=0.295). However, the main effect of time was significant (P≤0.001). This finding indicates that, across groups, there was a statistically significant difference in Mini-BEST scores after the training period. Table 5 presents significant differences between the pre-training assessment and the post-assessment (P≤0.001) and between the pre-assessment and the 6-month follow-up assessment (P≤0.001).

ABC score

The interaction effect of time within the group was not significant (P=0.657). 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 finding 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) and between the pre-assessment and the follow-up results (P<0.001).

FROP-Com scores

Regardig 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 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).

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 returned to normal after a rest.

Fourteen 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).

Discussion

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 dif-

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	Faller No.	Faller Odds	Exp. (β) (OR)	P (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	

Abbreviations: OR: Odds ratio; CI: Confidence interval; Exp. (β): Exponential β.

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	Faller No.	Faller Odds	Exp. (β) (OR)	P (95% CI)
FPBT (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	

Abbreviations: OR: Odds ratio; CI: Confidence interval; Exp. (β): Exponential β.

Table 5. Repeated measures analysis of within-group differences

Scale/Questionnaire	P	Mean±SD			P (95% CI)		
	Time (Main Effect)	Pre	Post	Follow-up	Pre vs Post	Post vs Follow-up	Pre vs Follow-up
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	71.4±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±5.8	11.22±5.32	0.001 (0.87, 4.32)	0.585 (-0.99, 3.21)	0.002 (0.99, 4.94)

Abbreviations: 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.

ference 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), suggesting 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 12% reduction in 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, performed 3 times a week for 8 weeks, reduced falls and injuries in stroke patients during a 6-month follow-up compared with single-task exercises (P<0.037). Similarly, Ahmad et al. (2021) reported that a high-intensity, multiplanar 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. 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. (2018) used the same duration as we did and found a significant reduction in fall risk in the DT group. In contrast, Ahmed et al. (2021) 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.

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 focused on single interventions that may be effective in non-stroke populations but not in stroke patients (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 (Batchelor et al., 2012a; 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.

Clinical tests

Researchers hypothesize that BBS and Mini-BEST scores would differ significantly across 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 BBS and Mini-BEST scores 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.

The initial level of instability influences improvements in balance following training (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 after 12 weeks of balance training, there was greater improvement in frontal plane balance compared to sagittal plane balance. Thus, the delayed improvement in sagittal-plane balance during the follow-up session may have contributed to the notable improvements in clinical balance (BBS scores) observed.

On the other hand, these results may indicate that BBS has limited sensitivity to detecting balance changes in the frontal plane, whereas the improvement was evident in the Mini-BEST test results (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 remained significant compared with 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. However, 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 differences did not reach significance (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% 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-taking, 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. Xu et al. (2018) 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. 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 (La Porta et al., 2022).

Xu et al. (2018) 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 of 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 (Batchelor et al., 2012b).

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 in fall rates or faller odds, both interventions demonstrated significant improvements in functional balance, balance confidence, and reduced fall risk 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 the addition of another group performing FPBT in a single-task context.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Research Ethics Committee the University of Social Welfare and Rehabilitation Sciences, Tehran, Iran (Code: IR.USWR.REC.1398.136). The present study was registered by the Iranian Registry of Clinical Trials (IRCT), Tehran, Iran (Code: IRCT20220703055350N1)

Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declaration of generative AI and AI-assisted technologies in the writing process

"Grammarly", an AI-assisted technology was used to check the text for grammar, spelling, punctuation, and style errors.

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Authors' contributions

Conceptualization, methodology, study design, data interpretation, and writing the original draft: Mitra Parsa, Iraj Abdollahi, Hossein Negahban, and Mohammad Ali Sanjari; Data acquisition: Mitra Parsa, Haniyeh Fakur Haddadiyan, and Mina Rouhani; Statistical analysis: Mitra Parsa and Enayatollah Bakhshi; Review and editing: Mitra Parsa, Mohammad Ali Sanjari, and Hossein Negahban; Final approval: All authors.

Conflict of interest

The authors declared no conflict of interest.

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References

Ahmed, U., Karimi, H., Amir, S., & Ahmed, A. (2021). Effects of intensive multiplanar trunk training coupled with dual-task exercises on balance, mobility, and fall risk in patients with stroke: A randomized controlled trial. *The Journal of International Medical Research*, *49*(11), 3000605211059413. [DOI:10.1177/03000605211059413] [PMID]

An, M., & Shaughnessy, M. (2011). The effects of exercise-based rehabilitation on balance and gait for stroke patients: A systematic review. *The Journal of Neuroscience Nursing*, *43*(6), 298-307. [DOI:10.1097/JNN.0b013e318234ea24] [PMID]

Ansari, N. N., Naghdi, S., Hasson, S., Valizadeh, L., & Jalaie, S. (2010). Validation of a mini-mental state examination (MMSE) for the Persian population: A pilot study. *Applied Neuropsychology*, *17*(3), 190–195. [DOI:10.1080/09084282.2010.499773] [PMID]

Batchelor, F., Hill, K., Mackintosh, S., & Said, C. (2010). What works in falls prevention after stroke? A systematic review and meta-analysis. *Stroke*, *41*(8), 1715-1722. [DOI:10.1161/STROKEAHA.109.570390] [PMID]

Batchelor, F. A., Hill, K. D., Mackintosh, S. F., Said, C. M., & Whitehead, C. H. (2012). Effects of a multifactorial falls prevention program for people with stroke returning home after rehabilitation: A randomized controlled trial. *Archives of Physical Medicine and Rehabilitation*, *93*(9), 1648-1655. [DOI:10.1016/j.apmr.2012.03.031] [PMID]

Batchelor, F. A., Mackintosh, S. F., Said, C. M., & Hill, K. D. (2012). Falls after stroke. *International Journal of Stroke*, *7*(6), 482-490. [DOI:10.1111/j.1747-4949.2012.00796.x] [PMID]

Berg, K., Wood-Dauphinee, S., & Williams, J. I. (1995). The balance scale: Reliability assessment with elderly residents and patients with an acute stroke. *Scandinavian Journal of Rehabilitation Medicine*, *27*(1), 27–36. [DOI:10.2340/1650197719952736] [PMID]

Botner, E. M., Miller, W. C., & Eng, J. J. (2005). Measurement properties of the activities-specific balance confidence scale among individuals with stroke. *Disability and Rehabilitation*, *27*(4), 156–163. [DOI:10.1080/09638280400008982] [PMID]

Cho, K., Lee, K., Lee, B., Lee, H., & Lee, W. (2014). Relationship between postural sway and dynamic balance in stroke patients. *Journal of Physical Therapy Science*, *26*(12), 1989–1992. [DOI:10.1589/jpts.26.1989] [PMID]

de Haart, M., Geurts, A. C., Huidekoper, S. C., Fasotti, L., & van Limbeek, J. (2004). Recovery of standing balance in postacute stroke patients: A rehabilitation cohort study. *Archives of Physical Medicine and Rehabilitation*, *85*(6), 886–895. [DOI:10.1016/j.apmr.2003.05.012] [PMID]

de Kam, D., Geurts, A. C., Weerdesteyn, V., & Torres-Oviedo, G. (2018). Direction-specific instability poststroke is associated with deficient motor modules for balance control. *Neurorehabilitation and Neural Repair*, *32*(6-7), 655–666. [DOI:10.1177/1545968318783884] [PMID]

Dean, C. M., Rissel, C., Sherrington, C., Sharkey, M., Cumming, R. G., & Lord, S. R., et al. (2012). Exercise to enhance mobility and prevent falls after stroke: The community stroke club randomized trial. *Neurorehabilitation and Neural Repair*, *26*(9), 1046–1057. [DOI:10.1177/1545968312441711] [PMID]

Ghai, S., Ghai, I., & Effenberg, A. O. (2017). Effects of dual tasks and dual-task training on postural stability: A systematic review and meta-analysis. *Clinical Interventions in Aging*, *12*, 557–577. [DOI:10.2147/CIA.S125201] [PMID]

Hassan, H., Zarrinkoob, H., Jafarzadeh, S., & Akbarzadeh, B. A. (2015). Psychometric evaluation of Persian version of activities-specific balance confidence scale for elderly Persians. *Auditory and Vestibular Research*, *24*(2), 4-13. [Link]

Hyndman, D., Ashburn, A., & Stack, E. (2002). Fall events among people with stroke living in the community: Circumstances of falls and characteristics of fallers. *Archives of Physical Medicine and Rehabilitation*, *83*(2), 165–170. [DOI:10.1053/apmr.2002.28030] [PMID]

La Porta, F., Lullini, G., Caselli, S., Valzania, F., Mussi, C., & Tedeschi, C., et al. (2022). Efficacy of a multiple-component and multifactorial personalized fall prevention program in a mixed population of community-dwelling older adults with stroke, Parkinson's disease, or frailty compared to usual care: The PRE.C.I.S.A. randomized controlled trial. *Frontiers in Neurology*, *13*, 943918. [DOI:10.3389/fneur.2022.943918] [PMID]

Lai, C. H., Chen, H. C., Liou, T. H., Li, W., & Chen, S. C. (2019). Exercise interventions for individuals with neurological disorders: A systematic review of systematic reviews. *American Journal of Physical Medicine & Rehabilitation*, *98*(10), 921–930. [DOI:10.1097/PHM.0000000000001247] [PMID]

Li, F., Wu, Y., & Li, x. (2014). Test-retest reliability and inter-rater reliability of the modified Tardieu scale and the modified ashworth scale in hemiplegic patients with stroke. *European Journal of Physical and Rehabilitation Medicine*, *50*(1), 9–15. [PMID]

Llorens, R., Latorre, J., Noé, E., & Keshner, E. A. (2016). Posturography using the Wii balance board™: A feasibility study with healthy adults and adults post-stroke. *Gait & Posture*, *43*, 228–232. [DOI:10.1016/j.gaitpost.2015.10.002] [PMID]

Low, D. C., Walsh, G. S., & Arkesteijn, M. (2017). Effectiveness of exercise interventions to improve postural control in older adults: A systematic review and meta-analyses of centre of pressure measurements. *Sports Medicine (Auckland, N.Z.), 47*(1), 101–112. [DOI:10.1007/s40279-016-0559-0] [PMID]

Maki, B. E., Edmondstone, M. A., & McIlroy, W. E. (2000). Age-related differences in laterally directed compensatory stepping behavior. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 55*(5), M270-M277. [DOI:10.1093/gerona/55.5.M270] [PMID]

Maki, B. E., Holliday, P. J., & Topper, A. K. (1994). A prospective study of postural balance and risk of falling in an ambulatory and independent elderly population. *Journal of Gerontology, 49*(2), M72-M84. [DOI:10.1093/geronj/49.2.M72] [PMID]

Mansfield, A., Aqui, A., Danells, C. J., Knorr, S., Centen, A., & DePaul, V. G., et al. (2018). Does perturbation-based balance training prevent falls among individuals with chronic stroke? A randomised controlled trial. *BMJ Open, 8*(8), e021510. [DOI:10.1136/bmjopen-2018-021510] [PMID]

Mansfield, A., Schinkel-Ivy, A., Danells, C. J., Aqui, A., Aryan, R., & Biasin, L., et al. (2017). Does perturbation training prevent falls after discharge from stroke rehabilitation? A prospective cohort study with historical control. *Journal of Stroke and Cerebrovascular Diseases: The Official Journal of National Stroke Association, 26*(10), 2174–2180. [DOI:10.1016/j.jstrokecerebrovasdis.2017.04.041] [PMID]

Melzer, I., Benjuya, N., & Kaplanski, J. (2004). Postural stability in the elderly: A comparison between fallers and non-fallers. *Age and Ageing, 33*(6), 602-607. [DOI:10.1093/ageing/afh218] [PMID]

Molhemi, F., Monjezi, S., Mehravar, M., Shaterzadeh-Yazdi, M. J., & Majdinasab, N. (2024). Validity, reliability, and responsiveness of Persian version of mini-balance evaluation system test among ambulatory people with multiple sclerosis. *Physiotherapy Theory and Practice, 40*(3), 565–575. [DOI:10.1080/09593985.2022.2119908] [PMID]

Myers, A. M., Powell, L. E., Maki, B. E., Holliday, P. J., Brawley, L. R., & Sherk, W. (1996). Psychological indicators of balance confidence: relationship to actual and perceived abilities. *The Journals of Gerontology. Series A, Biological sciences and Medical Sciences, 51*(1), M37–M43. [DOI:10.1093/gerona/51A.1.M37] [PMID]

Ng, M. M., Hill, K. D., Batchelor, F., & Burton, E. (2017). Factors predicting falls and mobility outcomes in patients with stroke returning home after rehabilitation who are at risk of falling. *Archives of Physical Medicine and Rehabilitation, 98*(12), 2433–2441. [DOI:10.1016/j.apmr.2017.05.018] [PMID]

Pang, M. Y. C., Yang, L., Ouyang, H., Lam, F. M. H., Huang, M., & Jehu, D. A. (2018). Dual-task exercise reduces cognitive-motor interference in walking and falls after stroke. *Stroke, 49*(12), 2990–2998. [DOI:10.1161/strokeaha.118.022157] [PMID]

Parsa, M., Rahimi, A., & Noorizadeh Dehkordi, S. (2019). Studying the correlation between balance assessment by biodex stability system and berg scale in stroke individuals. *Journal of Bodywork and Movement Therapies, 23*(4), 850–854. [DOI:10.1016/j.jbmt.2019.04.014] [PMID]

Plummer, P., Morris, M. E., & Dunai, J. (2003). Assessment of unilateral neglect. *Physical Therapy, 83*(8), 732-740. [DOI:10.1093/ptj/83.8.732] [PMID]

Russell, M. A., Hill, K. D., Blackberry, I., Day, L. M., & Dharmage, S. C. (2008). The reliability and predictive accuracy of the falls risk for older people in the community assessment (FROP-Com) tool. *Age and Ageing, 37*(6), 634–639. [DOI:10.1093/ageing/afn129] [PMID]

Salavati, M., Negahban, H., Mazaheri, M., Soleimanifar, M., Hadadi, M., & Sefiddashti, L., et al. (2012). The Persian version of the berg balance scale: Inter and intra-rater reliability and construct validity in elderly adults. *Disability and Rehabilitation, 34*(20), 1695–1698. [DOI:10.3109/09638288.2012.660604] [PMID]

Sawacha, Z., Carraro, E., Contessa, P., Guiotto, A., Masiero, S., & Cobelli, C. (2013). Relationship between clinical and instrumental balance assessments in chronic post-stroke hemiparesis subjects. *Journal of Neuroengineering and Rehabilitation, 10,* 95. [DOI:10.1186/1743-0003-10-95] [PMID]

Schinkel-Ivy, A., Inness, E. L., & Mansfield, A. (2016). Relationships between fear of falling, balance confidence, and control of balance, gait, and reactive stepping in individuals with sub-acute stroke. *Gait & Posture, 43,* 154-159. [DOI:10.1016/j.gaitpost.2015.09.015] [PMID]

Sherrington, C., Michaleff, Z. A., Fairhall, N., Paul, S. S., Tiedemann, A., & Whitney, J., et al. (2017). Exercise to prevent falls in older adults: An updated systematic review and meta-analysis. *British Journal of Sports Medicine, 51*(24), 1750–1758. [DOI:10.1136/bjsports-2016-096547] [PMID]

Silsupadol, P., Shumway-Cook, A., Lugade, V., van Donkelaar, P., Chou, L. S., & Mayr, U., et al. (2009). Effects of single-task versus dual-task training on balance performance in older adults: A double-blind, randomized controlled trial. *Archives of Physical Medicine and Rehabilitation, 90*(3), 381–387. [DOI:10.1016/j.apmr.2008.09.559] [PMID]

Stel, V. S., Smit, J. H., Pluijm, S. M., & Lips, P. (2003). Balance and mobility performance as treatable risk factors for recurrent falling in older persons. *Journal of Clinical Epidemiology, 56*(7), 659–668. [DOI:10.1016/S0895-4356(03)00082-9] [PMID]

Tsang, C. S., Liao, L. R., Chung, R. C., & Pang, M. Y. (2013). Psychometric properties of the mini-balance evaluation systems test (Mini-BESTest) in community-dwelling individuals with chronic stroke. *Physical Therapy, 93*(8), 1102-1115. [DOI:10.2522/ptj.20120454] [PMID]

Tuokko, H., Griffith, L. E., Simard, M., & Taler, V. (2017). Cognitive measures in the Canadian longitudinal study on aging. *The Clinical Neuropsychologist, 31*(1), 233-250. [DOI:10.1080/13854046.2016.1254279] [PMID]

Verheyden, G. S., Weerdesteijn, V., Pickering, R. M., Kunkel, D., Lennon, S., & Geurts, A. C., et al. (2013). Interventions for preventing falls in people after stroke. *The Cochrane Database of Systematic Reviews, 2013*(5), CD008728. [DOI:10.1002/14651858.CD008728.pub2] [PMID]

Winser, S. J., Tsang, W. W., Krishnamurthy, K., & Kannan, P. (2018). Does tai chi improve balance and reduce falls incidence in neurological disorders? A systematic review and meta-analysis. *Clinical Rehabilitation, 32*(9), 1157–1168. [DOI:10.1177/0269215518773442] [PMID]

Xu, T., Clemson, L., O'Loughlin, K., Lannin, N. A., Dean, C., & Koh, G. (2018). Risk factors for falls in community stroke survivors: A systematic review and meta-analysis. *Archives of Physical Medicine and Rehabilitation, 99*(3), 563–573.e5. [DOI:10.1016/j.apmr.2017.06.032] [PMID]

Yang, F., Lees, J., Simpkins, C., & Butler, A. (2021). Interventions for preventing falls in people post-stroke: A meta-analysis of randomized controlled trials. *Gait & Posture, 84,* 377-388. [DOI:10.1016/j.gaitpost.2020.12.034] [PMID]

Yang, S., Hwang, W. H., Tsai, Y. C., Liu, F. K., Hsieh, L. F., & Chern, J. S. (2011). Improving balance skills in patients who had stroke through virtual reality treadmill training. *American Journal of Physical Medicine & Rehabilitation, 90*(12), 969–978. [DOI:10.1097/PHM.0b013e3182389fae] [PMID]

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-m 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 all weight from the non-supporting leg.

Appendix

FPBT group exercises

Static exercises

● Semi-tandem standing

(If possible, foot positioning was altered during repetitions. Otherwise, the affected foot was placed forward.)

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