

# COMPARING THE EFFECTIVENESS OF SUSPENSION THERAPY AND CLOSED CHAIN EXERCISES FOR IMPROVING FUNCTIONAL OUTCOMES IN STROKE SURVIVORS: A RANDOMIZED CONTROL TRIAL

Original Research (ID: 1674)

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## ABSTRACT

**Background:** Stroke commonly leaves survivors with impaired balance, slow gait, and reduced independence, particularly during the subacute stage when recovery potential remains clinically important. Rehabilitation strategies that improve weight bearing, trunk control, and safe stepping are therefore central to functional recovery. Closed kinetic chain exercises are widely used for lower limb control, whereas suspension therapy may provide a safer environment for balance and gait training. Direct comparison of these approaches remains limited in stroke rehabilitation.

**Objective:** To compare the effectiveness of suspension therapy and closed kinetic chain exercises in improving balance and gait speed among patients with subacute stroke.

**Methods:** This parallel two-arm randomized controlled trial included 68 patients with subacute stroke who were randomly allocated to the closed kinetic chain exercise group (n = 34) or suspension therapy group (n = 34). Both groups received conventional physical therapy along with the assigned intervention for six weeks, five days per week, with each session lasting 30–45 minutes. Balance was assessed using the Berg Balance Scale, while gait speed was measured using the 10-Meter Walk Test at baseline and after intervention. Within-group changes were analyzed using the Wilcoxon signed-rank test, and between-group change scores were compared using the Mann–Whitney U test.

**Results:** No participant withdrew from the study. Both groups were similar in age and gender distribution at baseline. In the closed kinetic chain exercise group, Berg Balance Scale score improved from 28.0 to 43.0, with a median change of 15.0 (Z = -5.10, p < .001, r = .88), while gait speed improved from 0.330 m/s to 0.500 m/s, with a median change of 0.180 m/s (Z = -5.10, p < .001, r = .88). In the suspension therapy group, Berg Balance Scale score improved from 28.50 to 41.00, with a median change of 14.00 (Z = -5.09, p < .001, r = .87), while gait speed improved from 0.325 m/s to 0.485 m/s, with a median change of 0.165 m/s (Z = -5.09, p < .001, r = .87). Between-group differences were not statistically significant for Berg Balance Scale (p = .146) or 10-Meter Walk Test (p = .490).

**Conclusion:** Both suspension therapy and closed kinetic chain exercises significantly improved balance and gait speed in patients with subacute stroke. Neither intervention showed superiority, suggesting that both may be useful rehabilitation options depending on patient needs, therapist expertise, and available resources.

**Keywords:** Balance, Exercise Therapy, Gait, Rehabilitation, Stroke, Walking Speed, Weight-Bearing

## INTRODUCTION

Stroke remains one of the leading causes of mortality and long-term disability worldwide, leaving many survivors with persistent limitations in balance, gait, mobility, and functional independence. More than 70% of stroke survivors experience reduced walking speed and impaired balance, which not only restricts participation in daily activities but also increases the risk of falls and dependency (1, 2). These functional limitations are often closely linked with weakness, poor motor control, and asymmetry of the trunk and lower limbs. Since the trunk acts as the central link between upper and lower body movements, impaired trunk stability after stroke can negatively affect posture, weight shifting, balance recovery, and walking performance (3). Therefore, rehabilitation strategies that improve trunk control, postural stability, and lower limb function are essential for restoring independence in stroke survivors.

Functional recovery after stroke is time-sensitive, particularly during the early and subacute phases when the nervous system demonstrates greater potential for motor relearning and neuroplastic adaptation. Evidence suggests that recovery is usually more rapid during the first few weeks after stroke and tends to slow considerably after three to six months (4). This makes early, structured, and goal-directed rehabilitation especially important. Balance and gait-related interventions during this period may help patients regain confidence in movement, improve walking ability, and reduce fall risk. However, selecting the most effective therapeutic approach remains an important clinical question, particularly when different exercise methods appear beneficial but have not been directly compared in well-designed trials. Closed chain exercises are commonly used in stroke rehabilitation to improve lower limb stability, postural control, and functional movement. These exercises involve weight-bearing activities in which the distal part of the limb remains fixed, promoting joint approximation, proprioceptive input, and coordinated activation of multiple muscle groups (5). By encouraging controlled muscle recruitment and improving stability around the hip, knee, and ankle, closed chain exercises may support better balance and functional mobility in stroke survivors. Previous clinical findings indicate that closed kinetic chain exercises can improve lower limb activation and balance by enhancing the functional use of the affected limb (5). Despite their frequent use in rehabilitation settings, limited evidence is available regarding how their effects compare with newer neuromuscular training approaches aimed at improving trunk and balance control.

Suspension therapy, also known as sling exercise therapy, is an emerging rehabilitation approach that uses harness or sling-supported systems to partially unload body weight while allowing active movement in a controlled and safe environment. This method may reduce fear of falling and therapist dependency while enabling patients to perform challenging exercises with greater confidence (3, 6). The unstable nature of suspension-based training requires continuous postural adjustment, which may stimulate proprioceptors, improve neuromuscular feedback, and enhance activation of trunk and core muscles required for upright posture and balance (3, 6, 7). Suspension therapy has been widely explored in sports conditioning and musculoskeletal rehabilitation, particularly for core stability and low back pain; however, its role in post-stroke rehabilitation remains less clearly established (8, 9). Although both closed chain exercises and suspension therapy have theoretical and clinical value for improving motor control, balance, and functional mobility, direct evidence comparing these two approaches in stroke survivors is limited. This gap is important because clinicians require practical, evidence-based guidance when choosing interventions that can produce meaningful improvements in gait speed and balance during the subacute stage of stroke recovery. A clearer comparison may help determine whether suspension therapy offers additional benefits over conventional closed chain exercise training, or whether both approaches provide comparable functional gains.

Therefore, the present randomized controlled trial was designed to compare the effectiveness of suspension therapy and closed chain exercises for improving functional outcomes in patients with subacute stroke. The study specifically focused on balance and gait speed, as these outcomes are closely related to independence, safety, and quality of life after stroke. The objective was to determine whether six weeks of suspension therapy produces greater improvement in balance and gait speed compared with closed kinetic chain exercises in stroke survivors.

## METHODS

A parallel, two-arm randomized controlled trial was conducted among patients with subacute stroke who were receiving rehabilitation services at two rehabilitation centers between January 2024 and June 2024. A total of 156 patients with stroke were screened for eligibility. Patients were considered eligible if they were in the subacute stage of stroke, defined as 1–6 months after stroke onset, and had lower limb weakness or hemiparesis affecting gait and functional mobility. Patients were excluded if they had severe spasticity, defined as a Modified Ashworth Scale score greater than 3, uncontrolled hypertension, recent myocardial infarction, fixed contractures, severe musculoskeletal deformity of the lower limb, severe cognitive impairment, or any other neurological condition that could interfere with participation in therapy or outcome assessment. After screening, 72 patients fulfilled the inclusion criteria; however, four were excluded on the basis of the predefined exclusion criteria. Finally, 68 participants were enrolled and randomly allocated into two equal

groups: the Suspension Therapy group, consisting of 34 participants, and the Closed Kinetic Chain Exercise group, consisting of 34 participants, as shown in Fig. 1. The random allocation sequence was generated by an independent researcher who was not involved in patient assessment or treatment delivery. The same independent researcher enrolled participants and assigned them to the respective intervention groups to reduce the risk of selection bias. Written informed consent was obtained from all participants before enrollment after explaining the purpose, procedures, potential benefits, and possible risks of the study. The study was approved by the Superior University Ethics Committee under approval number SU-IRB-2024-015 and was conducted in accordance with the ethical principles of the Declaration of Helsinki.

Both groups received conventional stroke rehabilitation along with the allocated study intervention for six weeks. The treatment frequency was five sessions per week, and each session lasted approximately 30–45 minutes. Conventional rehabilitation included joint range-of-motion exercises, functional mobility training, and general therapeutic activities commonly used in stroke rehabilitation. These routine exercises were provided without the use of a suspension system or a specific closed kinetic chain exercise protocol, so that the additional effects of the study interventions could be compared more clearly. Participants allocated to the Suspension Therapy group received harness-supported gait and balance training under the supervision of a physical therapist. A safety suspension system was used to provide a secure training environment and to reduce the risk of falls while allowing active movement practice. During each session, the therapist remained beside or slightly behind the participant and provided standby guarding throughout the activity. A gait belt was applied around the participant's waist to allow immediate manual assistance if balance was lost. Continuous manual support was not provided unless it was required to prevent a fall or to help the participant regain postural control. Verbal instructions and encouragement were given throughout the session to improve posture, weight shifting, stepping control, and balance reactions. Assistive devices such as a cane, walker, or lower limb orthosis were used according to the participant's functional status and were kept consistent across sessions whenever possible. Training was performed in a clear, level, and safe area, with a chair or wall available nearby for rest or support. Sessions were discontinued if the participant developed light-headedness, excessive fatigue, discomfort, or if safety could not be maintained.

Participants in the Closed Kinetic Chain Exercise group received conventional weight-bearing exercise training based on their physical ability and functional status. The intervention included exercises in which the feet remained fixed on the floor or on a stable surface, such as squats, step-ups, lunges, and weight-shifting activities. These exercises were selected to promote lower limb loading, joint approximation, proprioceptive feedback, muscle co-activation, and functional control of the affected limb. The physical therapist supervised each session, corrected posture through verbal cues, monitored movement quality, and provided manual assistance only when required for safety or task completion. Fall prevention remained a priority during all exercises, and the level of difficulty was adjusted according to each participant's tolerance and performance. Baseline demographic and clinical information was collected at the time of enrollment, including age, gender, affected side, duration since stroke onset, and the type of assistive device used during training. Functional outcomes were assessed at baseline and after six weeks of intervention. The primary outcome measures were balance and gait speed. Balance was measured using the Berg Balance Scale, while gait speed was assessed using the 10-Meter Walk Test. Both tools are commonly used clinical outcome measures in stroke rehabilitation and provide practical information regarding postural control, walking performance, and functional mobility. Assessments were performed by a trained physical therapist using a standardized procedure at both assessment points.

Data were analyzed using SPSS version 26.0 for Windows (IBM Corp., Armonk, NY, USA). Since the data were summarized using median and interquartile range, non-parametric statistical tests were applied. Within-group changes from baseline to six weeks were analyzed using the Wilcoxon signed-rank test. Between-group comparisons of change scores for the Berg Balance Scale and 10-Meter Walk Test were performed using the Mann–Whitney U test. Continuous and ordinal baseline variables were also compared between groups using the Mann–Whitney U test, while categorical variables were analyzed using the Chi-square test. Effect size was calculated using the formula  $r = Z/\sqrt{N}$  and interpreted as small, medium, and large effects at values of 0.10, 0.30, and 0.50, respectively. A p-value of less than 0.05 was considered statistically significant.

## RESULTS

A total of 156 patients with stroke were screened between January 2024 and June 2024. Of these, 72 fulfilled the eligibility criteria, four were excluded, and 68 participants were enrolled and randomized equally into the Closed Chain Exercise group and the Suspension Therapy group. No withdrawals were reported during the study period; therefore, all 68 participants completed the six-week intervention and were included in the final analysis. The demographic distribution was broadly comparable between the two groups. Each group included 34 participants, with an equal gender distribution of 17 males and 17 females in both groups. Overall, 34 participants were male and 34 were female. Most participants were between 51 and 70 years of age. In the Closed Chain Exercise group, 15 participants were aged 51–60 years and 19 were aged 61–70 years, while no participant was aged 40–50 years. In the Suspension Therapy group, three participants were aged 40–50 years, 17 were aged 51–60 years, and 14 were aged 61–70 years. Across the total sample, three participants were aged 40–50 years, 32 were aged 51–60 years, and 33 were aged 61–70 years.

Both groups showed statistically significant improvements in balance and gait speed after six weeks of intervention. In the Closed Chain Exercise group, the median Berg Balance Scale score increased from 28.0 (IQR: 21.0–32.25) at baseline to 43.00 (IQR: 37.75–46.20) after intervention, with a median change of 15.00 (IQR: 14.00–17.00). This within-group improvement was statistically significant, with a large effect size ( $Z = -5.10, p < .001, r = .88$ ). In the Suspension Therapy group, the median Berg Balance Scale score increased from 28.50 (IQR: 20.75–32.00) to 41.00 (IQR: 36.00–46.20), with a median change of 14.00 (IQR: 11.75–17.00). This improvement was also statistically significant, with a large effect size ( $Z = -5.09, p < .001, r = .87$ ). Gait speed measured through the 10-Meter Walk Test also improved in both groups. In the Closed Chain Exercise group, median gait speed increased from 0.330 m/s (IQR: 0.258–0.383) at baseline to 0.500 m/s (IQR: 0.450–0.540) after six weeks, with a median change of 0.180 m/s (IQR: 0.150–0.200). The within-group change was statistically significant, with a large effect size ( $Z = -5.10, p < .001, r = .88$ ). In the Suspension Therapy group, median gait speed increased from 0.325 m/s (IQR: 0.250–0.365) to 0.485 m/s (IQR: 0.420–0.540), with a median change of 0.165 m/s (IQR: 0.145–0.200). This change was also statistically significant, with a large effect size ( $Z = -5.09, p < .001, r = .87$ ).

Between-group analysis of change scores showed no statistically significant difference between the two interventions. For Berg Balance Scale change scores, the Closed Chain Exercise group showed a median improvement of 15.00 (IQR: 14.00–17.00), while the Suspension Therapy group showed a median improvement of 14.00 (IQR: 11.75–17.00). The between-group difference was not statistically significant, with a small effect size ( $U = 460.0, Z = -1.46, p = .146, r = .18$ ). Similarly, for gait speed, the Closed Chain Exercise group showed a median improvement of 0.180 m/s (IQR: 0.150–0.200), compared with 0.165 m/s (IQR: 0.145–0.200) in the Suspension Therapy group. The between-group difference was not statistically significant, with a small effect size ( $U = 522.0, Z = -0.69, p = .490, r = .08$ ).

**Table 1 Demographic characteristics of participants n=68**

Outcome	Group	Pre Mdn (IQR)	Post Mdn (IQR)	Change Mdn (IQR)	Z	P value	r
<b>BBS</b>	Closed chain exercises (n=34)	28.0 (21-32.25)	43.00 (37.75-46.2)	15 (14.0-17.0)	-5.10	<.001	.88
	Suspension therapy(n=34)	28.50 (20.75-32.00)	41.00 (36.00-46.2)	14 (11.75-17.0)	-5.09	<.001	.87
<b>10MWT(m/s)</b>	Closed chain exercises (n=34)	0.330 (0.258-0.383)	0.500 (0.450-0.54)	0.180 (0.150-0.200)	-5.10	<.001	.88
	Suspension therapy(n=34)	0.325 (0.250-0.365)	0.485 (0.420-0.54)	0.165 (0.145-0.200)	-5.09	<.001	.87

**Table 2 Within-group changes in balance and gait speed from pre to post intervention**

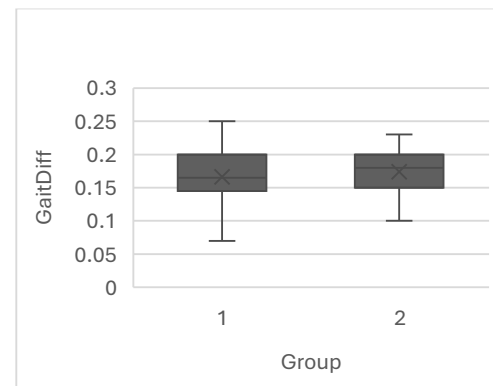
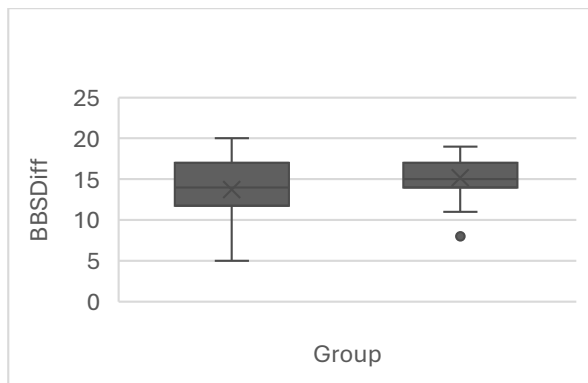
Variable	Closed chain exercise(n=34)	Suspension therapy(n=34)	Total (n=68)
Age, n%			
40-50	0	3 (8.8)	3 (4.4)
51-60	15 (44.1)	17 (50.0)	32 (47.1)
61-70	19 (55.9)	14 (41.2)	33 (48.8)
Gender, n%			
Male	17	17	34(50)
Female	17	17	34(50)

Note. Z and r values calculated from Wilcoxon signed-rank test;  $r = Z/\sqrt{N}$ .

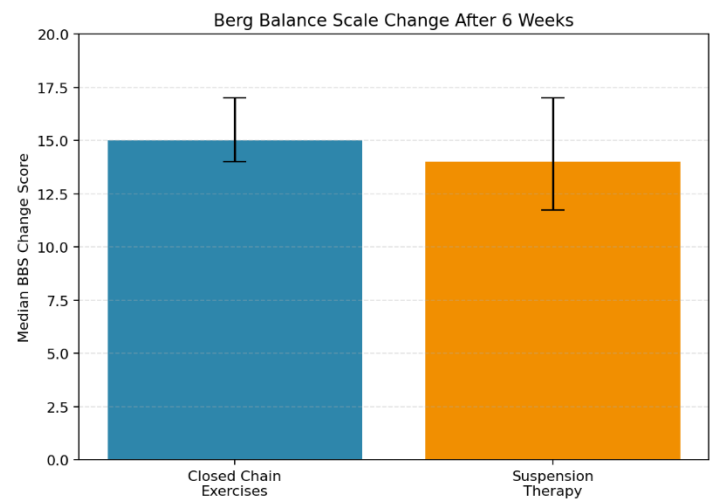
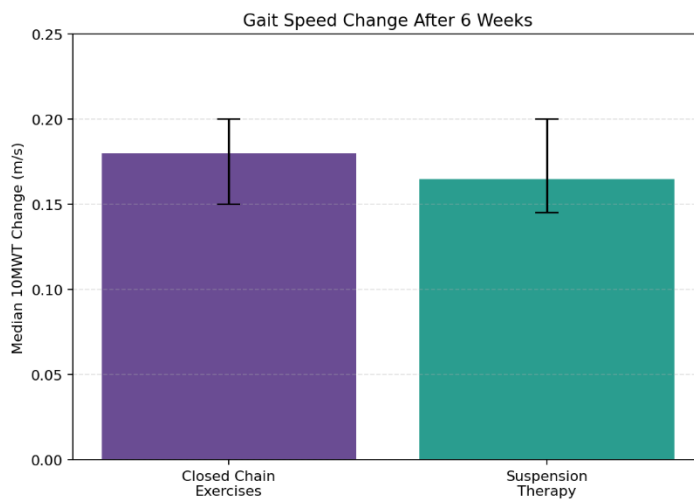
**Table 3 Between-group comparison of change scores**

Variables	Closed chain exercises	Suspension therapy	U	Z	P	r
BBS change score			460.0	-1.46	.146	.18
Mdn (IQR)	15 (14.00-17.00)	14.00 (11.75-17.00)				
Gait speed change(m/s)			522.0	-0.69	.490	.08
Mdn (IQR)	0.180 (0.15-0.20)	0.165 (0.150-0.200)				

Note. Mdn = Median, IQR = Interquartile Range. U, Z, r from Mann-Whitney U test.



**Figure 1** Between-group comparison of Berg Balance Scale change scores **Figure 2** Between-group comparison of 10-Meter Walk Test change scores



## DISCUSSION

The present randomized controlled trial showed that both closed chain exercises and suspension therapy produced significant improvements in balance and gait speed among patients with subacute stroke after six weeks of intervention. The Berg Balance Scale improved significantly in both groups, with a median gain of 15.00 points in the closed chain exercise group and 14.00 points in the suspension therapy group. Similarly, gait speed measured through the 10-Meter Walk Test increased by 0.180 m/s in the closed chain exercise group and 0.165 m/s in the suspension therapy group. These within-group improvements were statistically significant and demonstrated large effect sizes in both groups. However, the comparison of change scores between the two groups did not show statistically significant differences for either balance or gait speed. This finding suggested that, under a matched treatment frequency and duration, both interventions produced comparable short-term functional gains in patients with subacute stroke (10). The improvement observed in the suspension therapy group could be explained by the neuromuscular demands created during supported balance and gait training. Suspension-based training allows patients to perform active movements in a safer environment, particularly when balance confidence is reduced after stroke. By reducing the fear of falling and allowing repeated practice of controlled movements, suspension therapy may support postural adjustments, trunk activation, weight shifting, and stepping control. These mechanisms are consistent with previous evidence indicating that sling exercise therapy can improve trunk control through enhanced proprioceptive feedback, neuromuscular activation, and stimulation of stabilizing musculature (3). The median improvement of 14.00 points in Berg Balance Scale score and 0.165 m/s in gait speed indicated that suspension therapy contributed to measurable functional progress in balance and walking performance. These findings also supported the concept that suspension-based or harness-assisted training may help patients practice challenging movements with greater safety and confidence during stroke rehabilitation (6, 9, 10).

Closed chain exercises also produced substantial improvements in both outcome measures. This was clinically understandable because closed chain exercise training emphasizes weight-bearing, joint approximation, lower limb loading, proprioceptive stimulation, and coordinated agonist-antagonist muscle activation. These elements are highly relevant for patients with stroke, as impaired limb loading and poor postural control commonly restrict standing balance, gait initiation, and walking stability. The observed median Berg Balance Scale gain of 15.00 points and gait speed improvement of 0.180 m/s suggested that repeated closed chain tasks such as squats, step-ups,

lunges, and weight shifting may have enhanced lower limb control and functional mobility. This finding was consistent with previous work reporting that closed kinetic chain exercises improve lower limb function and balance through improved muscle activation and functional use of the affected limb (5). Since stroke rehabilitation aims to restore safe and efficient movement, the use of task-oriented, weight-bearing activities remains an important therapeutic approach, particularly during the early and subacute stages of recovery (11,12). The absence of a statistically significant difference between the two interventions should be interpreted with caution. It did not prove that both interventions were fully equivalent, because the study was not specifically designed as an equivalence or non-inferiority trial. Rather, the findings indicated that no statistically detectable superiority of one intervention over the other was observed within the available sample and six-week follow-up period. The small between-group effect sizes for Berg Balance Scale change scores and gait speed change scores further suggested that the difference in improvement between the groups was limited. This result may indicate that both approaches share common therapeutic mechanisms, including repeated functional practice, postural control training, neuromuscular activation, and progressive movement exposure. It also supported existing evidence that structured rehabilitative exercise improves physical function after stroke and that different exercise-based approaches may be beneficial when delivered with adequate intensity, supervision, and task specificity (12-15).

From a clinical perspective, these findings suggested that both closed chain exercises and suspension therapy may be useful options for improving balance and gait speed in patients with subacute stroke. In settings where suspension equipment is available, suspension therapy may be particularly helpful for patients who require additional safety support, have fear of falling, or need graded exposure to balance and gait activities. In contrast, closed chain exercises may be more practical in low-resource rehabilitation environments because they require minimal equipment and can be easily integrated into routine therapy sessions. Therefore, intervention selection may reasonably depend on patient tolerance, therapist expertise, safety needs, available equipment, and rehabilitation goals. The findings also emphasized that exercise dosage, supervision, and task-specific repetition may be as important as the specific modality used (16,17). A strength of this study was its randomized controlled design, which improved the internal validity of the findings. The equal allocation of participants into both groups and the absence of withdrawals also strengthened the completeness of the dataset. The use of clinically relevant outcome measures, including the Berg Balance Scale and 10-Meter Walk Test, enhanced the practical value of the results because these tools directly reflect balance ability and walking performance in stroke rehabilitation. Another strength was the six-week supervised intervention period, which allowed sufficient time to observe measurable functional changes while maintaining a structured treatment schedule (18,19).

Despite these strengths, several limitations needed consideration. The study had a relatively small sample size and was conducted over a short follow-up period, which limited the ability to determine long-term retention of functional gains. The absence of post-intervention follow-up meant that it remained unclear whether improvements in balance and gait speed were maintained after supervised therapy ended. The study also focused mainly on two functional outcomes and did not include broader measures such as activities of daily living, fall frequency, trunk impairment, quality of life, lower limb strength, spasticity changes, fatigue, or patient satisfaction. These additional outcomes could have provided a more complete understanding of functional recovery after stroke. Although demographic variables such as age and gender were reported, other important clinical characteristics, including affected side, duration since stroke onset, type of stroke, baseline severity, use of assistive devices, and comorbidities, required clearer reporting to better judge group comparability (20-22). Another methodological limitation was the need for greater clarity in the description of suspension therapy. The intervention was described as suspension-based training, but the exact nature of unloading, harness support, device specifications, and progression criteria needed more detailed explanation. This detail is important because suspension therapy may vary from simple safety support to partial body-weight-supported training, and these variations can influence therapeutic intensity and patient performance. Future studies should define the suspension protocol more precisely, including the amount of support, exercise progression, therapist assistance, safety monitoring, and adherence. Blinded outcome assessment, concealed allocation, and a prior sample size calculation should also be clearly reported in future trials to strengthen methodological transparency.

Future research should include larger multicenter trials with longer follow-up periods to determine whether the observed improvements are sustained over time. Studies should also compare different stroke severities, stages of recovery, and patient subgroups to identify which patients benefit most from each intervention. The addition of trunk control measures, functional independence scales, fall-related outcomes, walking endurance, balance confidence, and quality-of-life assessments would provide a broader picture of clinical benefit. Cost-effectiveness analysis may also be valuable, especially in rehabilitation settings where access to suspension equipment is limited. Further trials designed specifically as equivalence or non-inferiority studies would be required before concluding that suspension therapy and closed chain exercises are therapeutically equivalent. Overall, the findings indicated that both suspension therapy and closed chain exercises were associated with significant short-term improvements in balance and gait speed among patients with subacute stroke. Neither intervention demonstrated statistical superiority over the other within the six-week treatment period. These results supported the use of both approaches as practical rehabilitation options, while also highlighting the need for larger, methodologically robust studies to determine long-term effects, patient-specific indications, and the most efficient integration of these interventions into stroke rehabilitation programs.

## CONCLUSION

This study concluded that both suspension therapy and closed chain exercises were effective in improving balance and gait speed among stroke survivors. Neither intervention showed clear superiority, indicating that both approaches may be useful rehabilitation options when applied in a structured and supervised manner. Suspension therapy may be beneficial where additional safety support and confidence during movement are required, while closed chain exercises remain a practical and accessible choice for improving weight-bearing control and functional mobility. Overall, the findings support the use of both interventions in stroke rehabilitation and provide clinicians with flexible treatment options based on patient needs, available resources, and rehabilitation goals.

## AUTHOR CONTRIBUTION

Author	Contribution
Sunaiha Hafeez	Conceptualization, Methodology, Formal Analysis, Writing - Original Draft, Validation, Supervision
Muhammad Naveed Babur	Methodology, Investigation, Data Curation, Writing - Review & Editing
Dr Zohaib Shahid	Investigation, Data Curation, Formal Analysis, Software
Momna Amir Butt	Software, Validation, Writing - Original Draft
Saba Asif	Formal Analysis, Writing - Review & Editing
Usama Tariq	Writing - Review & Editing, Assistance with Data Curation

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