

Original Article

Effect of Proprioceptive Neuromuscular Facilitation (PNF) Pelvic Patterns Versus Elastic Band Resisted Gait Training on Balance and Lower Limb Proprioception in Subacute Stroke Patients

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Introduction

Stroke remains a major cause of mortality and long-term disability worldwide, with a particularly substantial and growing burden in low- and middle-income countries (1). Although advances in acute stroke management have improved survival, many stroke survivors continue to experience persistent limitations in mobility, balance, gait, and participation in daily activities. Access to structured rehabilitation also remains inadequate in many resource-constrained settings, further limiting functional recovery after stroke (2). Among the most disabling consequences are impaired postural control and balance, which increase the risk of falls and restrict independent mobility. These impairments are frequently influenced by disturbances in proprioception, the sensory ability to perceive joint position and movement and to appropriately regulate postural and motor responses (3). The early months following stroke are particularly important for neurological and functional recovery, and rehabilitation delivered during this period can contribute substantially to improvements in mobility and participation (4).

Proprioceptive impairment is common after stroke but may receive less clinical attention than motor weakness or spasticity. Somatosensory deficits, including impaired position sense, have been reported in a considerable proportion of stroke survivors and may adversely affect motor control and functional recovery (5). Lower-limb proprioception is especially relevant to standing and walking because accurate sensory information from the ankle, knee, and surrounding structures contributes to postural adjustments, weight transfer, and gait control. Differences in ankle joint position sense have been demonstrated across stroke survivors with different levels of walking ability, suggesting an important relationship between proprioceptive acuity and functional ambulation (6). Rehabilitation strategies that simultaneously address postural control, gait performance, and proprioceptive deficits may therefore provide meaningful functional benefits during the subacute stage of recovery.

Proprioceptive neuromuscular facilitation (PNF) is a therapeutic approach that uses specific diagonal and spiral movement patterns, manual contact, resistance, and sensory cues to facilitate coordinated neuromuscular activity (7). Pelvic control is particularly important during gait because coordinated pelvic motion contributes to trunk stability, weight transfer, lower-limb advancement, and overall walking efficiency. Interventions targeting the trunk and pelvis have been associated with improvements in trunk control, standing balance, and mobility following stroke (8). Pelvic PNF combined with core-strengthening approaches has also demonstrated beneficial effects on balance, gait, trunk control, and functional performance in individuals with stroke (9). A systematic review and meta-analysis of PNF-based physiotherapy reported improvements in balance and gait-related outcomes in people with chronic stroke, although variability in intervention protocols and methodological quality limits the certainty and generalizability of some findings (10). The need for continued systematic evaluation of PNF in stroke rehabilitation has also been recognized in prior review protocols examining its effects on functional activities and quality of life (11).

Elastic-band-assisted gait training represents a less resource-intensive rehabilitation strategy that may also enhance lower-limb motor control during walking. Elastic bands are inexpensive, portable, and capable of providing graded resistance or mechanical assistance, characteristics that may be particularly useful in settings where therapist time and rehabilitation resources are limited. In a randomized controlled trial involving stroke survivors, elastic-band-assisted gait training incorporated into task-oriented practice produced

improvements in gait kinematics, including gait velocity, cadence, and paretic-limb stride characteristics, compared with task-oriented gait training alone (12). Other studies using elastic walking bands or elastic-band orthoses have similarly reported improvements in gait and balance-related outcomes after stroke (13,14). More broadly, systematic evidence from older adults suggests that elastic-band resistance training can improve lower-limb strength and balance, supporting its potential value as a practical rehabilitation modality (15).

Despite evidence supporting both pelvic PNF and elastic-band-based interventions, comparatively little evidence directly examines their relative effects during the subacute stage of stroke rehabilitation. The two interventions may influence recovery through different therapeutic mechanisms. Pelvic PNF provides therapist-mediated sensory and manual facilitation directed toward coordinated pelvic and trunk movement, whereas elastic-band-assisted gait training provides task-specific resistance and external mechanical cues during walking. Determining whether these approaches differ in their effects on balance, walking speed, and lower-limb joint position sense is clinically important, particularly in resource-constrained settings where intervention intensity, therapist involvement, cost, and scalability may influence rehabilitation planning. A direct comparison may therefore help clarify whether one intervention offers advantages for specific dimensions of post-stroke motor recovery rather than assuming that either approach is uniformly superior.

Accordingly, the objective of this randomized controlled trial was to compare the effects of PNF pelvic pattern training and elastic-band-resisted gait training on balance, gait velocity, and lower-limb joint position sense in individuals with subacute stroke. Outcomes were assessed using the Berg Balance Scale, 10-Meter Walk Test, and ankle and knee joint position sense measurements. It was hypothesized that both interventions would improve balance, gait velocity, and proprioceptive performance over six weeks, with potentially different magnitudes of improvement across the measured outcomes.

Materials and Methods

An assessor-blinded, two-arm randomized controlled trial was conducted at Al-Majeed Poly Clinic, Lahore, Pakistan, to compare proprioceptive neuromuscular facilitation (PNF) pelvic pattern training with elastic-band-resisted gait training in adults with subacute stroke. Participants were recruited using convenience sampling from patients referred to the study setting who met the predefined eligibility criteria. Following enrollment, participants were randomly allocated to either the PNF group or the elastic-band group. The required sample size was estimated *a priori* using G*Power software, version 3.1.9.7, and the calculation indicated that a minimum of 35 participants was required for the planned comparison (16). The trial was conducted and reported with reference to the CONSORT statement for parallel-group randomized trials (17).

Adults aged 35–60 years were eligible if they had experienced either an ischemic or hemorrhagic stroke within the preceding 6 months, had hemiparesis resulting in unilateral motor impairment, were able to walk without physical assistance, had a Mini-Mental State Examination score of at least 24, and had a Berg Balance Scale score between 20 and 45, consistent with the balance impairment targeted in the study population (18–22). Participants were excluded if they had experienced a recurrent stroke, had severe spasticity, an unstable cardiac condition, a rheumatologic or orthopedic disorder that could interfere with mobility or assessment, an uncontrolled medical condition requiring immediate attention, or concurrent participation in another rehabilitation study (23,24).

Potential participants underwent clinical screening to determine eligibility. Eligible individuals received an explanation of the study procedures and were provided the opportunity to give written informed consent before participation. Participants were informed that participation was voluntary and that they could withdraw from the study at any time without obligation. After informed consent was obtained, each participant was assigned a unique identification number to maintain confidentiality. Participants were then randomized to one of the two intervention groups. Group allocation was concealed using sealed envelopes. Because both interventions involved active physiotherapy procedures, neither the participants nor the treating physiotherapists could be blinded to treatment allocation. Outcome assessment was performed by physiotherapists who remained blinded to group assignment throughout the assessment period, thereby reducing the risk of detection bias.

Both groups received supervised treatment for 60 minutes per session, 5 days per week, for 6 consecutive weeks, providing a total of 30 treatment sessions. The duration and frequency of therapist contact were kept equivalent between groups. All sessions were supervised by trained physiotherapists, who monitored participants for fatigue, discomfort, or instability and allowed rest periods when required. Participants requiring a break were positioned comfortably until they were able to continue the session.

Participants allocated to the PNF group received pelvic-pattern training based on established PNF principles (25). The intervention incorporated diagonal pelvic movement patterns, including anterior elevation with posterior depression and posterolateral elevation with anteromedial depression, performed in supine and side-lying positions as appropriate. Manual contact, assistance, and resistance were applied by the therapist during the prescribed movement patterns to facilitate coordinated pelvic and lower-limb neuromuscular activity. Participants allocated to the elastic-band group received task-oriented gait training with elastic resistance. Elastic-band assistance was used to facilitate appropriate timing of knee flexion and ankle dorsiflexion during the swing phase of gait and to assist hip movement during limb advancement. The elastic band was adjusted to approximately 25% tension for the prescribed training activities. Additional task-oriented gait exercises incorporating elastic resistance and visual and verbal feedback were used during treatment. Both intervention programs were delivered within the same scheduled treatment duration.

Balance was assessed using the Berg Balance Scale (BBS), a 14-item clinical measure of static and dynamic balance scored from 0 to 56, with higher scores indicating better balance performance. The BBS has demonstrated high reliability and validity for individuals with stroke (22). Walking speed was assessed using the 10-Meter Walk Test (10MWT), a standardized measure of functional gait velocity with established inter-rater and intra-rater reliability in people with post-stroke hemiparesis (26). Gait velocity was recorded in meters per second.

Lower-limb proprioception was evaluated through joint position sense (JPS) testing using active joint repositioning, an established clinical approach for assessing proprioceptive acuity (27). Ankle joint position sense was assessed at target positions of 0°, 30°, and 60°, while knee joint position sense was assessed at 0°, 45°, and 90°. For each target position, participants actively attempted to reproduce the designated joint angle, and the angular difference between the target position and the reproduced position was measured using a goniometer. This angular difference represented joint position error, with lower values indicating greater proprioceptive accuracy.

Outcome assessments were conducted at baseline before intervention initiation (Week 0), at the mid-intervention assessment (Week 3), and after completion of the intervention (Week 6). The same principal outcomes—BBS score, 10MWT gait velocity, and ankle and knee JPS error—were evaluated at each assessment point. Participant movements during intervention sessions were videotaped to support monitoring of treatment fidelity and compliance. Participants were observed throughout treatment for adverse events, fatigue, discomfort,

and instability. Any adverse event requiring interruption of treatment was to be documented, and further participation was dependent on the participant's clinical status and willingness to continue.

Statistical analyses were performed using IBM SPSS Statistics version 26.0 and Python. Continuous variables were summarized as mean $\pm$ standard deviation, while categorical variables were presented as frequencies and percentages. Distributional assumptions for continuous outcomes were assessed using the Shapiro–Wilk test together with graphical inspection of Q–Q plots and histograms. Baseline continuous variables were compared between the two intervention groups using independent-samples t-tests where parametric assumptions were considered appropriate, while categorical variables were compared using chi-square tests. Within-group changes between relevant assessment points were examined using paired-samples t-tests.

Changes in repeatedly measured outcomes across the three assessment occasions were evaluated using a 2×3 mixed-design analysis of variance, with intervention group as the between-subjects factor and time as the within-subjects factor. Time effects, group effects, and Group $\times$ Time interactions were evaluated to determine whether the pattern of change differed between the PNF and elastic-band groups. Where repeated-measures assumptions required correction, the Greenhouse–Geisser adjustment was applied. Partial eta-squared (η^2p) was used to quantify effect size for analysis-of-variance effects. Independent-samples t-tests were additionally used for selected between-group comparisons at individual assessment points, with Cohen's d used to describe standardized between-group effect magnitude.

The association between change in lower-limb proprioception and improvement in balance was explored using Pearson correlation between change in the composite JPS error measure and change in BBS score. An additional exploratory two-way analysis of variance examined BBS change according to intervention group and baseline balance severity, with baseline severity categorized using the sample median BBS value of 32.0. Group, baseline-severity, and Group $\times$ Severity effects were evaluated. All statistical tests were two-tailed, and a p -value <0.05 was considered statistically significant. No outcome data were reported as missing, and all 35 randomized participants completed the three scheduled assessments.

Ethical approval was obtained before participant recruitment from the Research Review Board under approval number IRB/FAHS/REHAB/04/26/MS/RS-4088. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki (28). Written informed consent was obtained from all participants before study participation. Participant confidentiality was maintained through the use of unique study identification numbers, and participants retained the right to discontinue participation at any stage.

Results

Forty-one patients were screened for eligibility. Six were not randomized, including four who did not meet the eligibility criteria and two who declined participation. The remaining 35 participants were randomized to the PNF group ($n = 18$) or elastic-band group ($n = 17$), and all randomized participants completed the 30-session intervention and all three assessments, giving a retention rate of 100%. Baseline demographic and clinical characteristics were generally similar between groups (Table 1). Mean age was 48.3 ± 7.7 years in the PNF group and 48.5 ± 6.7 years in the elastic-band group ($p = 0.955$). Baseline BBS scores, gait velocity, and ankle and knee JPS errors also showed not statistically significant between-group differences.

Balance increased overtime in both groups (Table 2). Mean BBS score increased from 31.9 ± 8.9 to 41.9 ± 7.3 in the PNF group and from 32.8 ± 5.6 to 39.5 ± 6.1 in the elastic-band group. The corresponding mean changes were 10.1 ± 3.1 and 6.7 ± 4.4 points. The derived between-group difference in change was 3.40 points (95% CI 0.75 to 6.05), with a standardized change-score effect size of $d = 0.90$. Mixed-design ANOVA demonstrated a substantial effect of time ($F = 117.60$, $p < 0.001$, $\eta^2p = 0.78$) and a Time $\times$ Group interaction ($F = 4.88$, $p = 0.011$, $\eta^2p = 0.13$), whereas the overall group effect was not significant ($F = 0.04$, $p = 0.836$).

Table 1. Baseline demographic, clinical, and outcome characteristics of participants (N = 35)

Variable	PNF group (n = 18)	Elastic-band group (n = 17)	p-value
Age, years	48.3 ± 7.7	48.5 ± 6.7	0.955
Male sex, n (%)	9 (50.0)	10 (58.8)	0.854
Female sex, n (%)	9 (50.0)	7 (41.2)	—
Ischemic stroke, n (%)	14 (77.8)	10 (58.8)	0.399
Hemorrhagic stroke, n (%)	4 (22.2)	7 (41.2)	—
Time since stroke, months	4.4 ± 1.2	4.2 ± 1.2	0.511
MMSE score	26.3 ± 2.1	27.6 ± 1.8	0.066
BBS score, /56	31.9 ± 8.9	32.8 ± 5.6	0.715
10MWT velocity, m/s	0.72 ± 0.12	0.76 ± 0.16	0.415
Ankle JPS error at 0°, °	6.8 ± 1.8	7.4 ± 1.6	0.255
Ankle JPS error at 30°, °	6.6 ± 2.3	7.4 ± 1.1	0.226
Ankle JPS error at 60°, °	6.5 ± 2.0	6.2 ± 2.3	0.669
Knee JPS error at 0°, °	6.2 ± 1.1	6.4 ± 1.5	0.679
Knee JPS error at 45°, °	7.8 ± 2.2	6.8 ± 1.4	0.110
Knee JPS error at 90°, °	6.2 ± 2.0	6.7 ± 1.9	0.437

Values are mean $\pm$ SD unless otherwise indicated. BBS, Berg Balance Scale; JPS, joint position sense; MMSE, Mini-Mental State Examination; PNF, proprioceptive neuromuscular facilitation; 10MWT, 10-Meter Walk Test. Continuous-variable p -values were obtained using independent-samples t-tests as reported in the manuscript. Categorical comparisons used chi-square tests with continuity correction.

Table 2. Changes in balance and gait velocity across the six-week intervention

Outcome	Group	Week 0, mean $\pm$ SD	Week 3, mean $\pm$ SD	Week 6, mean $\pm$ SD	Within-group change, mean $\pm$ SD	Between-group difference in change (95% CI)	Cohen's d for change	Time effect, F; p; η^2p	Group effect, F; p	Time $\times$ Group, F; p; η^2p
BBS, /56	PNF	31.9 $\pm$ 8.9	37.6 $\pm$ 8.3	41.9 $\pm$ 7.3	10.1 $\pm$ 3.1	3.40 (0.75 to 6.05)	0.90	117.60; <0.001; 0.78	0.04; 0.836	4.88; 0.011; 0.13
	Elastic band	32.8 $\pm$ 5.6	37.6 $\pm$ 5.5	39.5 $\pm$ 6.1	6.7 $\pm$ 4.4	—	—	—	—	—
10MWT, m/s	PNF	0.72 $\pm$ 0.12	0.77 $\pm$ 0.15	0.85 $\pm$ 0.18	0.14 $\pm$ 0.07	-0.08 (-0.16 to 0.003)	-0.69	72.46; <0.001; 0.69	1.44; 0.239	3.89; 0.025; 0.11
	Elastic band	0.76 $\pm$ 0.16	0.85 $\pm$ 0.24	0.97 $\pm$ 0.31	0.22 $\pm$ 0.15	—	—	—	—	—

Between-group differences in change were calculated as PNF minus elastic-band change from the reported change-score means, SDs, and group sizes. Positive values for BBS favor a larger increase in the PNF group; negative values for 10MWT indicate a larger increase in the elastic-band group. Confidence intervals were calculated using independent change-score comparisons. Cohen's d was calculated from the pooled SD of the reported change scores. Mixed-design ANOVA statistics are those reported in the manuscript. BBS, Berg Balance Scale; CI, confidence interval; PNF, proprioceptive neuromuscular facilitation; 10MWT, 10-Meter Walk Test; η^2p , partial eta-squared.

Table 3. Ankle and knee joint position sense error across assessment points

Joint/angle	Group	Week 0, mean $\pm$ SD, °	Week 3, mean $\pm$ SD, °	Week 6, mean $\pm$ SD, °	Week-6 mean difference, ° (95% CI)	Week-6 p-value	Cohen's d
Ankle 0°	PNF	6.8 $\pm$ 1.8	5.5 $\pm$ 1.7	3.9 $\pm$ 2.0	-1.80 (-3.14 to -0.46)	0.013	-0.92
	Elastic band	7.4 $\pm$ 1.6	6.5 $\pm$ 1.8	5.7 $\pm$ 1.9	—	—	—
Ankle 30°	PNF	6.6 $\pm$ 2.3	5.2 $\pm$ 2.3	4.0 $\pm$ 2.3	-1.60 (-2.85 to -0.35)	0.015	-0.88
	Elastic band	7.4 $\pm$ 1.1	6.5 $\pm$ 1.1	5.6 $\pm$ 1.1	—	—	—
Ankle 60°	PNF	6.5 $\pm$ 2.0	5.4 $\pm$ 2.1	3.9 $\pm$ 2.0	-0.50 (-2.11 to 1.11)	0.457	-0.22
	Elastic band	6.2 $\pm$ 2.3	5.4 $\pm$ 2.4	4.4 $\pm$ 2.6	—	—	—
Knee 0°	PNF	6.2 $\pm$ 1.1	5.0 $\pm$ 1.2	3.6 $\pm$ 1.3	-1.10 (-2.23 to 0.03)	0.054	-0.68
	Elastic band	6.4 $\pm$ 1.5	5.5 $\pm$ 1.7	4.7 $\pm$ 1.9	—	—	—
Knee 45°	PNF	7.8 $\pm$ 2.2	6.6 $\pm$ 2.3	5.2 $\pm$ 2.3	0.10 (-1.23 to 1.43)	0.963	0.05
	Elastic band	6.8 $\pm$ 1.4	6.0 $\pm$ 1.5	5.1 $\pm$ 1.5	—	—	—
Knee 90°	PNF	6.2 $\pm$ 2.0	5.1 $\pm$ 2.1	3.8 $\pm$ 2.1	-1.20 (-2.61 to 0.21)	0.095	-0.58
	Elastic band	6.7 $\pm$ 1.9	5.9 $\pm$ 1.8	5.0 $\pm$ 2.0	—	—	—

Week-6 mean differences were calculated as PNF minus elastic-band values. Negative differences indicate lower joint-position error in the PNF group. Confidence intervals and Cohen's d were calculated from the reported Week-6 means, SDs, and group sizes. Reported p-values are the manuscript's Week-6 between-group comparisons. JPS, joint position sense; PNF, proprioceptive neuromuscular facilitation.

Table 4. Association between proprioceptive and balance changes and exploratory analysis of baseline balance severity

Analysis	Comparison/effect	Estimate	p-value	η^2p
Correlation of change in composite JPS error with change in BBS	Overall sample	r = 0.32	0.065	—
	PNF group	r = 0.06	—	—
	Elastic-band group	r = -0.29	—	—
Two-way ANOVA of BBS change	Group	F = 7.17	0.012	0.19
	Baseline severity	F = 4.18	0.049	0.12
	Group $\times$ baseline severity	F = 0.96	0.334	—

Baseline balance severity was categorized using the reported median baseline BBS score of 32.0. BBS, Berg Balance Scale; JPS, joint position sense; PNF, proprioceptive neuromuscular facilitation; η^2p , partial eta-squared.

Gait velocity also increased across the intervention period. Mean 10MWT velocity increased from 0.72 $\pm$ 0.12 to 0.85 $\pm$ 0.18 m/s in the PNF group and from 0.76 $\pm$ 0.16 to 0.97 $\pm$ 0.31 m/s in the elastic-band group. Mean change was 0.14 $\pm$ 0.07 m/s with PNF and 0.22 $\pm$ 0.15 m/s with elastic-band training. The derived PNF-minus-elastic-band difference in change was -0.08 m/s (95% CI -0.16 to 0.003; d = -0.69). The repeated-measures analysis nevertheless showed a significant Time $\times$ Group interaction (F = 3.89, p = 0.025, η^2p = 0.11), together with a strong time effect (F = 72.46, p < 0.001, η^2p = 0.69); the overall group effect was not significant (F = 1.44, p = 0.239).

Joint-position error decreased numerically from baseline to Week 6 across all ankle and knee positions in both intervention groups (Table 3). At Week 6, ankle JPS error was lower in the PNF group than in the elastic-band group at 0°, with values of 3.9 $\pm$ 2.0° and 5.7 $\pm$ 1.9°, respectively. The corresponding mean difference was -1.80° (95% CI -3.14 to -0.46; p = 0.013; d = -0.92). A similar pattern was observed

at ankle 30°, where Week-6 errors were $4.0 \pm 2.3^\circ$ and $5.6 \pm 1.1^\circ$, yielding a mean difference of -1.60° (95% CI -2.85 to -0.35 ; $p = 0.015$; $d = -0.88$). The ankle 60° difference was smaller at -0.50° (95% CI -2.11 to 1.11 ; $p = 0.457$).

For knee JPS, the Week-6 mean error at 0° was $3.6 \pm 1.3^\circ$ in the PNF group and $4.7 \pm 1.9^\circ$ in the elastic-band group, corresponding to a mean difference of -1.10° (95% CI -2.23 to 0.03 ; $p = 0.054$; $d = -0.68$). Between-group differences were also not statistically significant at knee 45° or 90°. Thus, the clearest Week-6 between-group differences in proprioceptive error were observed at the ankle at 0° and 30°.

Across all 35 participants, change in the composite JPS error score showed a moderate positive correlation with change in BBS score ($r = 0.32$, $p = 0.065$), although the association did not reach the prespecified significance threshold (Table 4). The corresponding within-group correlations were weak in the PNF group ($r = 0.06$) and negative in the elastic-band group ($r = -0.29$). In the exploratory analysis of BBS change according to intervention group and baseline balance severity, the group effect ($F = 7.17$, $p = 0.012$, $\eta^2p = 0.19$) and baseline-severity effect ($F = 4.18$, $p = 0.049$, $\eta^2p = 0.12$) were statistically significant, whereas the Group $\times$ Severity interaction was not ($F = 0.96$, $p = 0.334$).

Discussion

The present randomized controlled trial compared PNF pelvic pattern training with elastic-band-resisted gait training in individuals with subacute stroke and found improvement over six weeks in balance, gait velocity, and lower-limb joint position sense in both intervention groups. The pattern of change, however, differed between the interventions. Balance improvement was greater in the PNF group, whereas gait velocity showed a greater increase over time in the elastic-band group. For proprioception, lower ankle joint position error at Week 6 was observed with PNF at 0° and 30°, while between-group differences at the knee were not statistically significant. Collectively, these findings suggest that the two rehabilitation approaches may have different relative strengths across balance, gait, and proprioceptive outcomes rather than one intervention demonstrating a uniform advantage across all measured domains.

The greater improvement in balance observed with pelvic PNF is biologically and clinically plausible given the contribution of pelvic and trunk control to postural stability and coordinated movement after stroke. Trunk-training interventions have previously been associated with improvements in trunk control, standing balance, and mobility in individuals after stroke (8). Similarly, pelvic PNF combined with core-strengthening exercises has been reported to improve trunk performance, balance, gait, and functional outcomes in people with chronic stroke (9). A systematic review and meta-analysis of PNF-based physiotherapy also identified improvements in balance and gait outcomes following stroke, although heterogeneity among intervention protocols and methodological limitations of the included studies should be considered when interpreting the evidence (10). The present findings are broadly consistent with this literature and extend the comparison to an active elastic-band gait-training intervention during the subacute stage of recovery.

Several mechanisms may contribute to the observed balance response to pelvic PNF. PNF uses diagonal movement patterns, manual resistance, tactile input, and proprioceptive stimulation to facilitate coordinated neuromuscular activity (7). Pelvic patterns may influence postural control by facilitating coordinated activation of the trunk and pelvic musculature and by improving weight transfer and control of the pelvis during functional movement. These mechanisms are consistent with evidence indicating that interventions directed toward trunk and pelvic control can improve postural performance after stroke (8,9). Nevertheless, the present trial did not directly measure muscle activation, trunk control, neural adaptation, or sensory integration; therefore, these mechanisms should be regarded as plausible explanations rather than demonstrated mechanisms of treatment effect.

Elastic-band-resisted gait training showed a different pattern, with a greater increase in gait velocity over time than PNF training. This finding is consistent with previous work examining elastic-band-assisted gait interventions in stroke rehabilitation. Visoi and colleagues reported improvements in gait kinematics following elastic-band-assisted gait training, including changes in gait velocity, cadence, and paretic-limb characteristics (12). Improvements in gait-related outcomes have also been reported with elastic walking bands and elastic-band orthoses in individuals with stroke (13,14). More broadly, elastic-band resistance exercise has demonstrated beneficial effects on lower-limb strength and balance in older adults, although findings from that population cannot be directly generalized to individuals with subacute stroke (15). The task-specific nature of the elastic-band intervention in the present study may partly explain the observed gait-velocity response because the resistance and assistance were incorporated directly into repetitive walking practice.

The gait-velocity findings should nevertheless be interpreted cautiously. Although the mixed-design analysis demonstrated a Time $\times$ Group interaction, the derived between-group difference in change was -0.08 m/s (95% CI -0.16 to 0.003) when expressed as PNF minus elastic-band change. Thus, the direction of the estimate favored a larger increase with elastic-band training, but the confidence interval from the simple change-score comparison narrowly included zero. In addition, gait velocity did not satisfy the reported normality assumption. These findings indicate that the apparent comparative advantage of elastic-band training for gait velocity warrants confirmation in a larger trial using a statistical approach appropriate to the outcome distribution.

Ankle joint position sense demonstrated another potentially important pattern. At Week 6, the PNF group had lower joint-position errors than the elastic-band group at ankle 0° and 30°, with between-group differences of -1.80° and -1.60° , respectively. These observations are consistent with the proprioceptive emphasis of PNF, in which manual contact, resistance, and movement patterns provide repeated sensory and neuromuscular input (7). Proprioceptive impairment is clinically relevant after stroke because somatosensory deficits may interfere with motor control and functional recovery (5), and ankle joint position acuity has been associated with different levels of walking ability among stroke survivors (6). However, the reported ankle comparisons were based on between-group differences at Week 6 rather than clearly demonstrated Group $\times$ Time interactions for each JPS outcome. Consequently, these findings support differences in ankle proprioceptive performance at follow-up but should not be interpreted as definitive evidence that PNF produced a greater longitudinal treatment effect on proprioception.

No statistically significant between-group differences were observed for knee joint position error at Week 6. At knee 0°, the estimated difference favored lower error with PNF but narrowly crossed the null value, whereas differences at 45° and 90° were less pronounced. The differing patterns between ankle and knee outcomes may reflect differences in the sensory and motor demands of the interventions, but the present data do not establish the underlying explanation. Further investigation using standardized repeated proprioceptive measurements and longitudinal treatment-effect analyses would be required to determine whether pelvic PNF has joint- or angle-specific effects on lower-limb proprioception.

The exploratory analysis also indicated that participants with greater baseline balance impairment showed larger absolute changes in BBS scores. Interpretation of this finding requires caution because the analysis categorized participants according to the sample median

and involved a relatively small total sample. Participants beginning with lower BBS scores may have had greater numerical scope for improvement, whereas individuals with higher initial scores may have been more susceptible to the known ceiling limitations of the BBS in stroke rehabilitation (29). Ceiling effects have been documented when balance recovery approaches the upper range of the scale, particularly among individuals achieving higher functional levels (30). Importantly, the absence of a Group $\times$ Severity interaction does not support the conclusion that baseline balance severity meaningfully modified the comparative response to the two interventions.

The findings may have practical relevance for stroke rehabilitation in settings where treatment resources and therapist availability are constrained. PNF pelvic pattern training requires direct therapist involvement for manual contact, resistance, and facilitation, whereas elastic-band-assisted gait training uses inexpensive and portable equipment and incorporates resistance directly into task-oriented walking practice. The differing outcome patterns observed in this study suggest that intervention selection may reasonably consider the rehabilitation domain being targeted. However, the present findings do not establish that elastic-band training can replace therapist-delivered PNF, nor was a combined intervention evaluated. Comparative effectiveness, cost-effectiveness, treatment burden, and the potential value of combining the approaches therefore remain questions for future investigation.

Several features strengthen the interpretation of the study, including randomized allocation to two active interventions, blinded outcome assessment, equivalent scheduled treatment frequency and duration between groups, repeated assessment at three time points, use of established clinical outcome measures, and complete follow-up of all 35 randomized participants. Nevertheless, important limitations should be considered. The trial was conducted at a single center with a small sample of 35 participants, limiting precision and generalizability. Participants and treating physiotherapists could not be blinded because of the nature of the interventions, creating potential performance-related influences. The absence of a usual-care or non-intervention control group also means that improvements within either group cannot be separated completely from spontaneous neurological recovery, concurrent recovery processes, repeated testing, or other time-related effects during the subacute period.

Additional analytical and measurement limitations should also be acknowledged. Gait velocity was not normally distributed despite the use of parametric longitudinal analyses. Multiple outcomes and joint angles were evaluated, increasing the number of statistical comparisons. The JPS findings were principally reported as Week-6 between-group comparisons rather than longitudinal interaction effects, limiting conclusions regarding differential change over time. Joint position sense was measured clinically using goniometry, and the study did not examine longer-term retention of treatment effects beyond six weeks. The exploratory baseline-severity analysis was based on a median split and should not be considered confirmatory. Finally, functional outcomes such as activities of daily living, participation, quality of life, and longer-term community mobility were not evaluated. Larger, adequately powered trials with longer follow-up, clearly prespecified primary outcomes, robust longitudinal analyses, and broader measures of functional recovery would help determine the reproducibility and clinical importance of the outcome-specific patterns observed in this study.

Conclusion

Both PNF pelvic pattern training and elastic-band-resisted gait training were associated with improvements in balance, gait velocity, and lower-limb joint position sense over the six-week intervention in individuals with subacute stroke. The PNF group demonstrated a greater improvement in balance and lower ankle joint position error at selected angles at Week 6, whereas gait velocity showed a greater increase over time in the elastic-band group. Neither intervention demonstrated a consistent advantage across all measured outcomes. These findings indicate that PNF pelvic patterns and elastic-band-resisted gait training may offer different outcome-specific benefits within subacute stroke rehabilitation, although the small sample size, short follow-up, and analytical limitations warrant cautious interpretation of their comparative effects.

DECLARATIONS

Author Contributions:	Concept and Design: AA; Data Collection and Analysis: AA; Drafting: AA, RI, TS; Editing: RI, JF; Proofreading: JF.
Ethical Approval:	Ethical approval was obtained from the Research Review Board under approval number IRB/FAHS/REHAB/04/26/MS/RS-4088. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.
Informed Consent:	Written informed consent was obtained from all participants before enrollment in the study.
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AI Declaration:	Generative AI tools were used solely for language and grammatical refinement. The authors verified the final manuscript and remain fully responsible for its accuracy, integrity, and scientific content.

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