Research Square

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Effects of sixteen weeks of two high-intensity flexibility training methods (dynamic versus static) on joint range of motion (ROM) in older adults: a comparative quasi-experimental study

Ronaldo Vivone Varejão
Federal University of the State of Rio de Janeiro (UNIRIO)
Karollyni Bastos Andrade Dantas
Tiradentes University (UNIT)
Fabio Henrique De Freitas
freitash2004@gmail.com
Federal University of the State of Rio de Janeiro (UNIRIO)
Everton dos Santos Araújo
Tiradentes University (UNIT)
Carlos Soares Pernambuco
Fluminense Federal University (UFF)
Estélio Henrique Martin Dantas
Federal University of the State of Rio de Janeiro (UNIRIO)

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Abstract

Background

Aging progressively reduces joint range of motion (ROM), affecting functional autonomy and fall risk. It remains uncertain whether dynamic flexibility training, stick-assisted, differs from static mat-based flexibility training in ROM gains among older adults. This study compared the effects of sixteen weeks of two flexibility training methods on joint ROM in older adults.

Methods

Comparative quasi-experimental study (reported according to STROBE) with two non-randomized groups — Dynamic (stick-assisted) and Static (mat-based) — assessed at baseline and after 16 weeks (three sessions per week). ROM for nine movements was measured by goniometry following the LABIFIE protocol, and intensity was controlled by PERFLEX (scores 81–90). Normality was assessed with Shapiro-Wilk and homogeneity with baseline t-test and Levene's test. Paired t-tests (and Wilcoxon when indicated) examined within-group changes; analyses between groups used analysis of covariance (ANCOVA, baseline as covariate), reporting partial η^2 and 95% CI; $\alpha = 0.05$. Multiple comparisons were addressed with Benjamini–Hochberg (FDR), with Bonferroni as a conservative check.

Results

Complete paired data were analyzed for the Dynamic Group (n = 87) and the Static Group (n = 98). The Static Group showed significant gains in cervical rotation ($\Delta = +5.4°$; $p < 0.001$; $d = 0.68$) and hip extension ($\Delta = +5.2°$; $p = 0.025$; $d = 0.40$); the Dynamic Group showed no significant gains. Hip extension was significantly greater with the static method, including after baseline adjustment (ANCOVA: $p = 0.002$; partial $\eta^2 = 0.161$). Both groups reduced shoulder horizontal flexion and shoulder adduction/abduction and hip flexion.

Conclusions

After 16 weeks, static mat-based flexibility training was associated with ROM gains in cervical rotation and hip extension and was superior to stick-assisted dynamic flexibility training for hip extension; mechanical assistance from the stick did not translate into gains. Reductions in some shoulder and hip movements suggest caution when applying high-intensity protocols in older adults. Findings are preliminary (no control group, no randomization).

Background

Aging produces deleterious effects on muscle strength, body composition and flexibility, impairing health and functional autonomy [1]. Progressive reductions in joint range of motion (ROM), muscle elasticity and mobility, exacerbated by physical inactivity, limit activities of daily living — dressing, putting on

shoes, reaching objects, getting in and out of vehicles — and increase fall risk, a leading cause of fractures (notably hip), hospitalizations and mortality in older adults.

Flexibility is a determinant of efficiency in activities of daily living and therefore of quality of life and functional autonomy in older adults [2, 3]; regular exercise attenuates aging effects, improves autonomy and benefits cognition [4, 5]. Various modalities produce gains in strength, aerobic fitness and flexibility [6–8]. Distinctions are made between stretching (submaximal work) and flexibility training (high-intensity, carried to the maximal tolerable amplitude): static high-intensity flexibility training is effective for flexibility gains, while dynamic methods integrate strength and coordination [9–13]. Such interventions have potential to improve autonomy and reduce falls in older adults [12, 15].

Despite this, it remains uncertain whether stick-assisted dynamic high-intensity flexibility training — which provides mechanical assistance — offers advantages over static mat-based high-intensity flexibility training in older adults. The objective of this study was to compare the effects of sixteen weeks of these two methods on joint ROM in older adults.

Methods

Design and setting

Comparative quasi-experimental study with two non-randomized groups assessed at two time points — pre-test (diagnostic assessment) and post-test after 16 weeks of intervention [16]. The report follows STROBE recommendations for observational studies [20]. Data collection occurred in 2002 within a community exercise program for older adults, with goniometry standardized by the LABIFIE protocol and intensity monitored by PERFLEX.

Rationale for using historical data. The analyzed dataset is a rare longitudinal collection: few studies directly compare dynamic and static high-intensity flexibility training in older adults with objective intensity control, and much available evidence addresses acute or short-term protocols. The record combines standardized goniometry (LABIFIE) and intensity monitoring (PERFLEX) over 16 weeks with individual pre–post pairing — methodological features difficult to reproduce in current community programs. Secondary analysis of well-documented historical datasets is an established and valid scientific practice when limitations are disclosed and ethical compliance ensured. In this case, retrospective ethical approval (2026) regularized secondary use of the data under applicable legislation.

Participants and eligibility criteria

Eligible participants were older adults (≥ 60 years) enrolled in a community program, without acute contraindications to mobility tests. Individuals with a history of fracture in the evaluated joints within the past five years were excluded. Allocation followed the method practiced: Dynamic Group (stick-assisted flexibility training) and Static Group (mat-based static flexibility training). For paired analyses (complete

data at both time points), the Dynamic Group included 87 participants and the Static Group 98. Baseline characteristics are shown in Table 1.

Variables and outcomes

The primary outcome was joint ROM (degrees) in nine movements: cervical rotation; shoulder horizontal flexion, shoulder horizontal extension, shoulder adduction/abduction and shoulder flexion; trunk flexion; hip flexion and hip extension; and knee flexion. The exposure variable was flexibility training method (dynamic vs. static). Perceived intensity (PERFLEX) was recorded as a control covariate.

Data sources and measurement

ROM was measured by goniometry in standardized positions according to the LABIFIE protocol [17] by a trained assessor in the morning. A steel goniometer (Lafayette, USA), 180° scale and 1° precision, was used. Effort intensity was monitored with the Perceived Exertion in Flexibility Scale (PERFLEX), a dimensionless five-level instrument (0–110): 0–30 (normality/mobility), 31–60 (forcing/stretching), 61–80 (discomfort/flexibility training), 81–90 (tolerable pain/possibility of injury) and 91–110 (strong pain/injury) [17]. Mean scores fell in the high-intensity range for both groups — Dynamic 85.2 ± 4.1 and Static 83.9 ± 4.6 — with no significant difference ($p > 0.05$). The data are available from the corresponding author and will be provided upon reasonable request. The complete LABIFIE protocol used in this study is available in full in the institutional repository: https://openrit.grupotiradentes.com/server/api/core/bitstreams/1609562a-a403-4b18-b3a5-af29eb66ca23/content.

Intervention protocols

Both groups performed three sessions weekly for 16 weeks. Each movement was executed in three sets of three repetitions, with a 15 s hold at the maximal tolerable amplitude, 10–15 s between repetitions and 30–60 s between sets. Intensity was prescribed in the high-intensity flexibility training range (PERFLEX ≥ 81 points, range 81–90), and observed mean scores were 83.9–85.2, confirming this target (see Data sources and measurement). The Dynamic Group performed flexibility training via dynamic movements assisted by a stick; the Static Group maintained static positions on a mat [9, 17].

Bias control

To reduce measurement bias, goniometry followed the standardized LABIFIE protocol, performed by a trained assessor under similar time and environmental conditions at each assessment. Intensity was standardized using PERFLEX. Baseline comparability between groups was checked (Table 1). Because there was no randomization, potential baseline differences were considered in interpretation. Risk of bias was assessed with ROBINS-I (Risk Of Bias In Non-randomized Studies of Interventions). Detailed

evaluation is in Supplementary Material 2. Overall risk of bias was rated moderate, mainly due to the quasi-experimental non-randomized design and baseline imbalances in two movements. These potential biases were addressed via ANCOVA adjustment for baseline values and sensitivity analyses.

Study size

Sample size corresponded to participants in the community program with complete data at both time points (Dynamic n = 87; Static n = 98). This is a convenience sample without an a priori sample size calculation; effect sizes and 95% CIs were reported to aid interpretation of magnitude and precision.

Quantitative variables and statistical analysis

Analyses were performed in R (v. 4.x) and SPSS (v. 28). Normality of change scores was assessed by Shapiro–Wilk; group homogeneity by independent-samples t-test at baseline and Levene's test. Within-group changes (pre vs. post) were tested with paired-samples t-tests; when normality was violated, Wilcoxon tests were used as sensitivity analyses. Between-group differences were primarily assessed by ANCOVA, with post-test as dependent variable, group as factor and pre-test as covariate — an approach suitable for non-randomized groups with baseline differences, estimating group effect adjusted for baseline. Estimated marginal means (adjusted) and partial η^2 were reported; the homogeneity of regression slopes assumption was checked via group × covariate interaction. As sensitivity, independent-samples t-tests were applied to change scores (Δ = post − pre) with Welch correction. For within-group changes, means ± standard deviations, mean differences with 95% CI and effect sizes (Cohen's d and Hedges' g with small-sample correction) were reported.

Power analysis. As a secondary analysis of an existing sample, no a priori sample calculation was performed; a sensitivity power analysis was conducted ($\alpha = 0.05$ two-tailed; power = 0.80). With available sample sizes, the study had power to detect, in within-group comparisons, effects from $d_z = 0.61$ (Dynamic, n = 23) and $d_z = 0.50$ (Static, n = 34) and, between groups, effects from $d = 0.77$. Multiple comparisons control. Given nine movement evaluations, type I error from multiplicity was controlled by Benjamini–Hochberg (FDR), applied separately to between-group (ANCOVA) and within-group comparisons, with Bonferroni correction reported as a conservative check; effect sizes and 95% CIs were considered alongside adjusted p-values.

Ethical considerations

Data handling complied with Brazilian Law No. 14.874/2024 [18] and the General Data Protection Law (LGPD, Law No. 13.709/2018) [19]. As a retrospective secondary analysis, the project was approved by the Research Ethics Committee of Universidade Tiradentes (UNIT) on 18/02/2026 (Opinion No. 8.176.512; CAAE 26524719.4.0000.5371). Consent was obtained at the time of original data collection. All experiments were performed in accordance with relevant guidelines and regulations (such as the

Declaration of Helsinki). Statement about informed consente: Written informed consent to participate in the study was obtained from all participants.

Results

Baseline characteristics, normality and homogeneity

Baseline characteristics are presented in Table 1. Age did not differ between groups (p = 0.280) and the sample comprised women only. At baseline, groups were comparable for most movements (independent-samples t-test, p > 0.05), with significant differences only in shoulder horizontal flexion (p = 0.036) and hip flexion (p = 0.026). Shapiro–Wilk indicated normality of change scores for most movements; for observed deviations (shoulder movements in both groups), Wilcoxon tests confirmed conclusions. Homogeneity of variances (Levene) was met except for shoulder horizontal extension (p = 0.030).

Table 1
Baseline characteristics and pre-intervention joint range of motion (ROM), by group.

Characteristic	Dynamic Group (n = 87)	Static Group (n = 98)	p
Age, years (Mean ± SD)	66.5 ± 7.9	64.7 ± 6.0	0.280
Female sex, n (%)	87 (100)	98 (100)	—
Body mass, kg (Mean ± SD) †	68.4 ± 10.8	68.4 ± 10.8	—
Height, m (Mean ± SD) †	1.56 ± 0.06	1.56 ± 0.06	—
BMI, kg/m² (Mean ± SD) †	28.1 ± 4.2	28.1 ± 4.2	—
Baseline ROM — cervical rotation, ° (Mean ± SD)	74.0 ± 11.0	69.1 ± 9.4	0.087
Baseline ROM — shoulder horizontal flexion, ° (Mean ± SD)	63.9 ± 13.3	71.6 ± 13.2	0.036*
Baseline ROM — shoulder horizontal extension, ° (Mean ± SD)	133.3 ± 25.3	137.2 ± 14.8	0.513
Baseline ROM — shoulder adduction/abduction, ° (Mean ± SD)	90.0 ± 20.5	98.1 ± 9.6	0.088
Baseline ROM — shoulder flexion, ° (Mean ± SD)	159.4 ± 25.7	162.7 ± 9.5	0.568
Baseline ROM — trunk flexion, ° (Mean ± SD)	74.3 ± 14.0	77.2 ± 12.0	0.416
Baseline ROM — hip flexion, ° (Mean ± SD)	88.2 ± 14.9	97.4 ± 14.7	0.026*
Baseline ROM — hip extension, ° (Mean ± SD)	167.8 ± 9.2	166.4 ± 11.9	0.616
Baseline ROM — knee flexion, ° (Mean ± SD)	50.8 ± 8.9	51.6 ± 12.5	0.794

Mean ± SD: mean ± standard deviation; ROM: joint range of motion. p: independent-samples t-test (age and baseline ROM). * $p < 0.05$. Sex was obtained from program records. † Anthropometric data refer to the total sample (n = 187). Prepared by authors, 2026.

Within-group changes and between-group comparison

Within-group changes. The Static Group showed statistically significant gains in cervical rotation (+ 5.4°; $p < 0.001$) and hip extension (+ 5.2°; $p = 0.025$); the Dynamic Group showed no significant gains (hip extension showed a reduction of − 5.3° that did not reach significance; $p = 0.065$). Both groups significantly reduced shoulder horizontal flexion, shoulder adduction/abduction and hip flexion; the Static Group also reduced knee flexion. Tables 2 and 3 and Fig. 1 detail within-group changes.

Between-group comparison (ANCOVA). Adjusting for baseline (Table 4), the homogeneity of regression slopes assumption was met for all movements (group × covariate interaction, $p > 0.05$). Hip extension showed a significant difference between groups favoring static flexibility training (adjusted means 171.8° vs. 162.3°; $F = 10.34$; $p = 0.002$; partial $\eta^2 = 0.161$, large effect). Shoulder adduction/abduction showed a borderline, non-significant difference ($p = 0.051$; partial $\eta^2 = 0.069$). No other movements differed significantly between groups. Sensitivity analysis on change scores agreed with these results (hip extension, $p = 0.004$).

After correction for multiple comparisons, the between-group difference in hip extension remained significant (Bonferroni and FDR, adjusted $p = 0.018$). Among within-group changes, FDR-adjusted significance remained for the Static Group's gain in cervical rotation (adjusted $p = 0.002$) and the reductions in shoulder horizontal flexion, shoulder adduction/abduction and hip flexion (both groups), as well as knee flexion in the Static Group; the Static Group's within-group hip extension gain was attenuated to borderline (FDR adjusted $p = 0.050$). The observed effect in hip extension ($d \approx 0.88$) exceeded the minimum detectable effect ($d = 0.77$), corresponding to power ≈ 0.89.

Table 2
Joint range of motion (degrees) — cervical, shoulder and trunk (pre, post and change), by group.

Joint	Group	n	Pre (Mean ± SD)	Post (Mean ± SD)	Δ [95% CI]	t (p)	d (g)
Cervical rotation	Dynamic (Stick)	87	74.0 ± 11.0	74.6 ± 11.4	+ 0.6 [− 4.1; +5.2]	0.25 (0.803)	+ 0.05 (+ 0.05)
	Static (Mat)	98	69.1 ± 9.4	74.5 ± 8.2	+ 5.4 [+ 2.6; +8.2]	3.97 (0.000*)	+ 0.68 (+ 0.67)
Shoulder horizontal flexion	Dynamic (Stick)	87	63.9 ± 13.3	53.5 ± 10.4	−10.4 [− 18.5; −2.3]	−2.66 (0.014*)	−0.56 (− 0.54)
	Static (Mat)	98	71.6 ± 13.2	56.6 ± 10.0	−15.0 [− 20.1; −9.9]	−6.00 (0.000*)	−1.03 (− 1.01)
Shoulder horizontal extension	Dynamic (Stick)	87	133.3 ± 25.3	127.5 ± 25.2	−5.8 [− 17.4; +5.8]	−1.03 (0.313)	−0.22 (− 0.21)
	Static (Mat)	98	137.2 ± 14.8	130.9 ± 19.7	−6.2 [− 14.4; +1.9]	−1.55 (0.131)	−0.27 (− 0.26)
Shoulder adduction/abduction	Dynamic (Stick)	87	90.0 ± 20.5	72.7 ± 8.6	−17.3 [− 26.5; −8.1]	−3.92 (0.001*)	−0.82 (− 0.79)
	Static (Mat)	98	98.1 ± 9.6	83.5 ± 21.5	−14.7 [− 22.5; −6.9]	−3.82 (0.001*)	−0.66 (− 0.64)
Shoulder flexion	Dynamic (Stick)	87	159.4 ± 25.7	158.0 ± 31.7	−1.5 [− 20.0; +17.1]	−0.17 (0.870)	−0.03 (− 0.03)
	Static (Mat)	98	162.7 ± 9.5	163.0 ± 21.0	+ 0.4 [− 7.0; +7.7]	0.10 (0.923)	+ 0.02 (+ 0.02)
Trunk flexion	Dynamic (Stick)	87	74.3 ± 14.0	77.3 ± 13.7	+ 3.0 [− 2.7; +8.6]	1.08 (0.291)	+ 0.23 (+ 0.22)
	Static (Mat)	98	77.2 ± 12.0	76.1 ± 12.5	−1.1 [− 6.0; +3.8]	−0.45 (0.656)	−0.08 (− 0.08)

* $p < 0.05$ (paired-samples t-test within group). Mean ± SD: mean ± standard deviation; 95% CI: 95% confidence interval of the mean change; d: Cohen's d; g: Hedges' g. Between-group comparisons are in

Table 4 (ANCOVA). Prepared by authors, 2026.

Table 3
Joint range of motion (degrees) — hip and knee (pre, post and change), by group.

Joint	Group	n	Pre (Mean ± SD)	Post (Mean ± SD)	Δ [95% CI]	t (p)	d (g)
Hip flexion	Dynamic (Stick)	87	88.2 ± 14.9	80.0 ± 13.7	−8.3 [−14.7; −1.9]	−2.68 (0.014*)	−0.56 (−0.54)
	Static (Mat)	98	97.4 ± 14.7	87.7 ± 14.7	−9.8 [−14.7; −4.8]	−4.02 (0.000*)	−0.69 (−0.67)
Hip extension	Dynamic (Stick)	87	167.8 ± 9.2	162.6 ± 11.1	−5.3 [−10.9; +0.4]	−1.94 (0.065)	−0.41 (−0.39)
	Static (Mat)	98	166.4 ± 11.9	171.6 ± 11.9	+ 5.2 [+ 0.7; +9.8]	2.34 (0.025*)	+ 0.40 (+ 0.39)
Knee flexion	Dynamic (Stick)	87	50.8 ± 8.9	49.5 ± 8.9	−1.3 [−5.6; +2.9]	−0.65 (0.521)	−0.14 (−0.13)
	Static (Mat)	98	51.6 ± 12.5	46.1 ± 8.1	−5.5 [−9.7; −1.3]	−2.68 (0.012*)	−0.47 (−0.46)

*p < 0.05 (paired-samples t-test within group). The four hip extension values in the Dynamic Group identified as data-entry errors were corrected according to the original records (see Methods). Between-group comparisons are in Table 4 (ANCOVA). Prepared by authors, 2026.

Table 4
Between-group comparison by analysis of covariance (ANCOVA), with pre-test as covariate.

Movement	Adjusted mean — Dynamic	Adjusted mean — Static	F	p	Partial η²
Cervical rotation	73.0°	75.6°	1.35	0.250	0.024
Shoulder horizontal flexion	53.6°	56.5°	0.99	0.325	0.018
Shoulder horizontal extension	128.3°	130.4°	0.14	0.711	0.003
Shoulder adduction/abduction	73.3°	83.1°	3.99	0.051	0.069
Shoulder flexion	157.9°	163.1°	0.53	0.469	0.010
Trunk flexion	78.0°	75.6°	0.56	0.457	0.010
Hip flexion	82.7°	85.8°	0.81	0.372	0.015
Hip extension	162.3°	171.8°	10.34	0.002*	0.161
Knee flexion	49.6°	46.0°	2.88	0.095	0.052

Adjusted means: estimated marginal means at the mean value of the pre-test. F and p refer to the group effect adjusted for baseline; partial η² = effect size (0.01 small; 0.06 medium; 0.14 large). Homogeneity of slopes (group × covariate interaction) was met for all movements ($p > 0.05$). * $p < 0.05$. Prepared by authors, 2026.

Effect sizes and confidence intervals

Effect sizes (Cohen's d and Hedges' g) and 95% CIs for mean changes are shown in Tables 2 and 3 and Fig. 1. Among significant findings, Static Group gains showed moderate effects for cervical rotation (d = 0.68; g = 0.67; 95% CI + 2.6 to + 8.2°) and hip extension (d = 0.40; g = 0.39; 95% CI + 0.7 to + 9.8°). Significant reductions ranged from moderate to large, notably shoulder horizontal flexion in the Static Group (d = − 1.03; g = − 1.01) and shoulder adduction/abduction in the Dynamic Group (d = − 0.82; g = − 0.79).

Discussion

This study compared, over 16 weeks, two high-intensity flexibility training methods — dynamic (stick-assisted) and static (mat-based) — on joint ROM in older women. The main finding indicates that the static method was associated with significant ROM gains, particularly in cervical rotation and hip extension, with a between-group difference favoring the static method for hip extension. This difference remained after baseline adjustment via ANCOVA (partial η² = 0.161; large effect), suggesting a low

likelihood that the finding is explained solely by initial group imbalances. Results do not support the hypothesis that mechanical assistance from a stick enhances flexibility gains superiorly.

Physiologically, the findings align with classic mechanisms linked to increased ROM. Sustained maintenance at high stretch amplitudes may favor adaptations related to stretch tolerance and tissue viscoelastic behavior (stress relaxation), processes dependent on time under tension with chronic effects on muscle extensibility [11, 13]. Conversely, dynamic flexibility training involves greater neuromuscular control and active movement production across the range, with less time at the stretch limit, which may yield less pronounced ROM adaptations though potential neuromotor and coordination benefits [9, 10]. In this context, the superior static-method response for hip extension suggests greater sensitivity of this movement to sustained stretch stimuli of the involved structures.

A noteworthy finding was ROM reduction in both groups for certain shoulder movements (horizontal flexion and adduction/abduction) and in hip flexion. This behavior may relate to both protocols being executed in the high-intensity PERFLEX range (81–90), corresponding to elevated discomfort levels that can elicit protective neuromuscular responses and limit ROM gains in more stabilizing joints such as the shoulder complex. Although plausible, this interpretation is indirect and was not directly measured. Additionally, differences in movement nomenclature between groups and possible measurement variability should be considered when interpreting these results, as well as statistical effects such as regression to the mean.

Gains in cervical rotation and hip extension have potential functional relevance because these movements relate to essential components of mobility: gaze orientation, postural stability, stride length and gait efficiency. Maintenance or improvement of these joint patterns may contribute to preservation of functional mobility in older adults [2, 15]. Although effects observed are of moderate magnitude and achieved with a simple low-cost intervention, interpretation should be cautious because direct functional outcomes were not assessed.

Previous evidence indicates flexibility interventions can increase ROM in older populations [11], while static stretching has been associated with reduced passive stiffness and improved muscle extensibility [13]. Prior studies also suggest effects of different flexibility modalities depend on stimulus specificity [9, 10]. Thus, current results add evidence by directly comparing dynamic and static methods under comparable intensity and duration over 16 weeks.

A systematic review by Linhares et al. reported that multicomponent training in women with osteoporosis can improve bone mineral density, strength, flexibility, balance, functional fitness and quality of life, and reduce fall risk. Other exercise types (aerobic, resistance and flexibility) were also presented for this population, highlighting the importance of diverse exercise forms as treatment for osteoporosis in older women. Considering the present study’s outcomes, improvements in ROM could contribute to prevention across several organ systems [21].

Zocher and Toda (2023) discuss that hippocampal neural stem cells generate new neurons throughout life, contributing to cognitive flexibility and mood regulation; however, adult hippocampal neurogenesis declines substantially with age. Epigenetic alterations emerge as central features of aging, and recent work suggests deterioration of neural stem cell epigenetic profiles is a determinant of age-dependent decline in adult neurogenesis. These considerations may apply to the age group studied here [22].

Strengths and limitations

Key strengths include use of standardized goniometry (LABIFIE protocol), systematic intensity control via PERFLEX, prolonged intervention duration (16 weeks), pre–post pairing, and reporting of effect sizes and confidence intervals, along with sensitivity analyses and control for multiple comparisons.

Limitations include the quasi-experimental non-randomized design and absence of a control group, limiting causal inference. Use of historical data (2002), although methodologically justified, imposes contextual constraints. The convenience sample comprised exclusively women, limiting generalizability. Losses to follow-up and the absence of direct functional and clinical outcomes restrict interpretation of practical relevance of ROM gains. Despite statistical controls, residual biases and measurement variability cannot be entirely excluded.

Finally, although the study had adequate power to detect moderate to large effects, the possibility of type II error for small effects should be considered. Future research should employ randomized designs, larger and more diverse samples, and include functional and clinical outcomes to deepen understanding of the effects of different modalities and intensities of flexibility training in older populations.

Conclusions

In older women, after 16 weeks, static mat-based high-intensity flexibility training was associated with ROM gains in cervical rotation and hip extension and was superior to stick-assisted dynamic flexibility training for hip extension, while the dynamic method did not produce significant gains. Observed reductions in some shoulder and hip movements suggest caution when using high-intensity protocols in older adults. Controlled randomized trials with larger samples, longitudinal follow-up and functional outcomes are recommended.

Declarations

Ethics approval and consent to participate:

Approved by CEP/UNIT on 18/02/2026 (Opinion No. 8.176.512; CAAE 26524719.4.0000.5371); consent obtained at original data collection.

Consent for publication:

Not applicable.

Competing interests:

The authors declare no competing interests.

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Author Contribution

RVV, EHMD. Data curation: KBAD, ESA. Formal analysis: KBAD, FHF. Investigation: RVV. Methodology: FHF, CSP. Project administration: EHMD. Supervision: CSP, EHMD. Validation: ESA. Writing — original draft: RVV. Writing — review & editing: KBAD, FHF, ESA, CSP, EHMD. All authors read and approved the final manuscript.

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Authors' information: Not applicable.

Data Availability

The data are available from the corresponding author and will be provided upon reasonable request.

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Figures

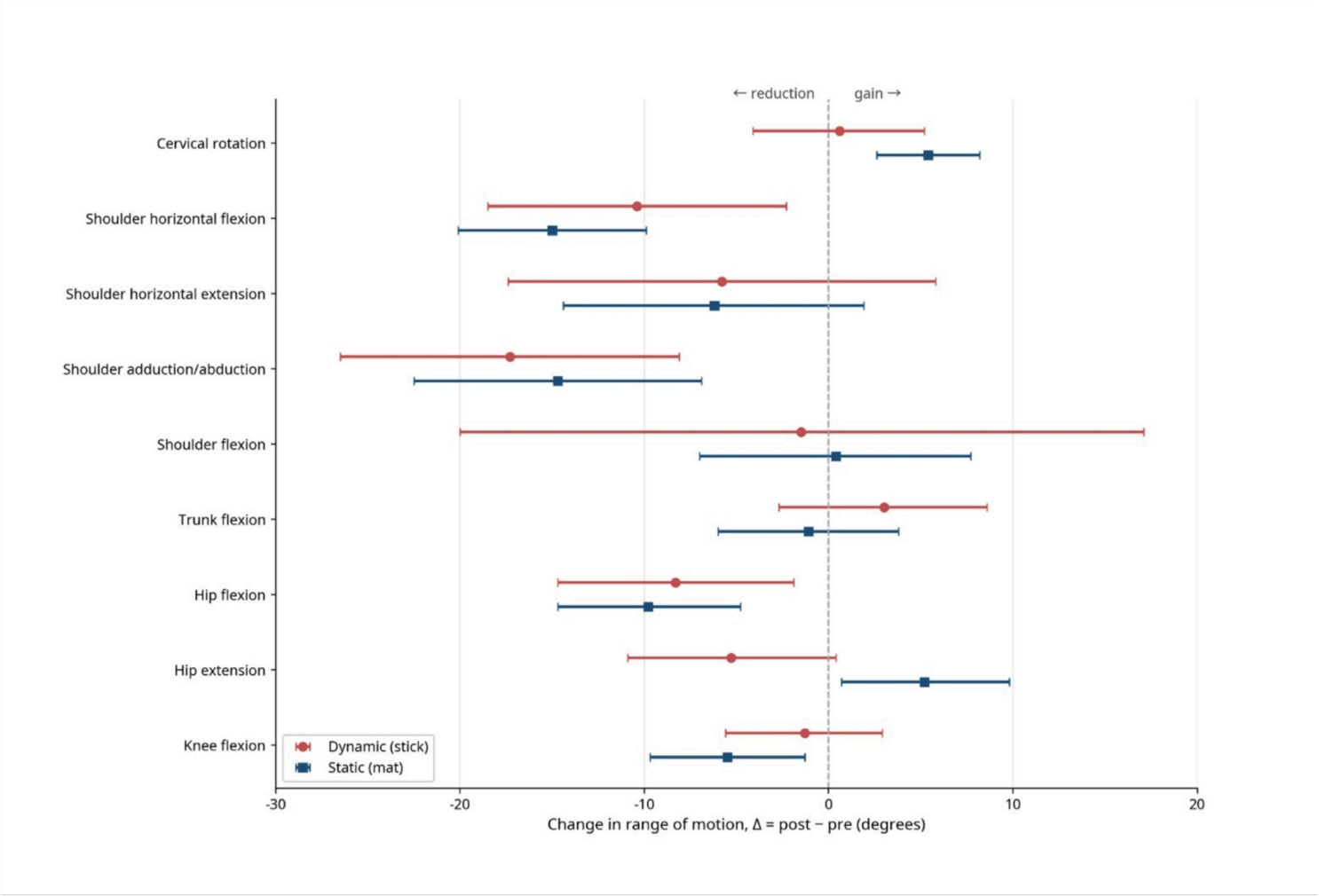


Figure 1

Change in range of motion (Δ = post − pre, in degrees) with 95% confidence interval, by movement and group. Markers to the right of the dashed line (Δ = 0) indicate gain; markers to the left indicate reduction. Prepared by authors, 2026.

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