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Predictors of gait function among geriatric individuals living with chronic stroke

Gait predictors in chronic stroke

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Abstract

Aim: Gait impairment is a major cause of disability in older adults following stroke. Lower extremity spasticity and trunk muscle dysfunction are common post-stroke impairments; however, their relative contribution to gait performance in geriatric individuals with chronic stroke has not been clearly established.

Methods: This cross-sectional observational study included geriatric individuals (≥ 65 years) living with chronic stroke. Lower extremity spasticity at the hip, knee, and ankle joints was assessed using the Modified Ashworth Scale. Trunk flexor and extensor muscle strength was evaluated using an isokinetic dynamometer at an angular velocity of 60°/s. Gait performance was assessed using the Tinetti Performance-Oriented Mobility Assessment. Associations between variables were analyzed using correlation analysis, and multiple linear regression was performed to identify independent predictors of gait performance.

Results: Gait performance was significantly and negatively correlated with spasticity levels at the hip, knee, and ankle joints, indicating that increased spasticity was associated with poorer gait function. Among these, ankle spasticity demonstrated the strongest independent association with gait performance. No significant associations were found between trunk flexor or extensor muscle strength and gait performance; therefore, trunk muscle strength was not retained as a predictor in the regression model.

Conclusion: Lower extremity spasticity, particularly at the ankle joint, is a primary determinant of gait performance in geriatric individuals with chronic stroke, whereas trunk muscle strength does not independently predict walking ability. These findings highlight the importance of targeting distal spasticity in rehabilitation strategies aimed at improving gait function in this population.

Keywords

geriatric, stroke, chronic, gait, spasticity

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Introduction

Walking is a fundamental motor skill that enables individuals to interact with their environment, maintain independence in daily activities, and preserve quality of life. However, age-related structural and functional changes in the musculoskeletal, nervous, and sensory systems lead to notable impairments in walking performance.¹ When a stroke is factored into this scenario, its effect on gait performance becomes even more significant. Chronic stroke observed in older adults further restricts mobility due to additional motor impairments such as muscle weakness, abnormal muscle tone (spasticity), and loss of postural control.²

Stroke survivors have identified walking recovery as a high-priority research need, and gait impairments persist in many individuals even three months after stroke.³ The combination of advanced age and post-stroke spasticity magnifies the challenge of regaining gait function, as elevated muscle tone contributes to abnormal gait.⁴ Several studies have explored the relationship between spasticity and gait function within this population. For instance, the prevalence of lower limb spasticity can impair balance and gait, leading to reduced walking speed and increased reliance on wheelchairs and caregiver support.⁵ Specific gait parameters, such as walking smoothness, are adversely affected by pronounced spasticity.⁶

The trunk plays a crucial role in maintaining stability and postural control, which are essential for efficient and coordinated gait performance. Previous studies have demonstrated that trunk strength is significantly associated with length of hospital stay, balance performance, and patients' ability to perform transfer activities.^{7,8} Although the adverse effects of spasticity on gait have been widely documented, the relative contribution of trunk strength—particularly in older adults who already exhibit age-related declines in postural control—remains underexplored.

This study aims to determine the extent to which lower extremity spasticity and trunk muscle strength predict gait performance in geriatric individuals with chronic stroke, thereby enhancing understanding of gait performance and informing strategies to improve mobility and functional independence.

Materials and Methods

Participants

This study was conducted with 30 geriatric individuals diagnosed with chronic hemiplegia following a stroke. Participants were included in the study if they have a diagnosis of hemorrhagic or ischemic stroke confirmed by computed tomography (CT) or magnetic resonance imaging (MRI), have no history of a previous stroke, were diagnosed with stroke at least 6 months prior to the study following a cerebrovascular event, are 65 years of age or older, and scored 3 or above on the Functional Ambulation Classification (FAC). Participants were excluded from the study if they had an additional neurological disorder other than stroke, had undergone surgical intervention within the past 6 months, or had any visual or hearing impairment.

Procedure

Participants were recruited from a university hospital's neurorehabilitation outpatient clinic between December and January 2025/2026.

All assessments were performed by the same experienced physiotherapist to ensure reliability. Demographic and clinical data, including age, sex, height, weight, body mass index (BMI), affected side, and dominant side, were recorded.

Outcome Measures

Assessment of spasticity: Lower-extremity spasticity was evaluated using the Modified Ashworth Scale (MAS), which grades muscle tone on a 6-point scale from 0 (no increase in muscle tone) to 4 (rigid in flexion or extension). In the MAS, the level of resistance to passive joint range of motion in the extremity is measured. Spasticity was assessed on the affected side by passively moving the joints and evaluating resistance in the hip flexors, knee flexors, and ankle plantarflexors. The mean score from these regions was used for subsequent analysis.⁹ The MAS is widely used in individuals with stroke to assess spasticity and to aid in understanding motor impairment severity as well as rehabilitation outcomes.^{10,11}

Trunk muscle strength: Trunk flexor and extensor muscle strength were assessed using an isokinetic dynamometer (e.g., Biodex System 4 Pro, Biodex Medical Systems, Shirley, NY, USA). Participants were securely positioned in the dynamometer chair, with the pelvis and thighs stabilized by straps to minimize compensatory movements. The range of motion determined for the participants during trunk movements was 65°, extending from 15° of trunk extension to 50° of trunk flexion. This range represents the trunk motion typically observed during activities of daily living.¹² After a warm-up and familiarization trial, three maximal voluntary contractions were performed at an angular velocity of 60°/s, and the peak torque values (Nm) for trunk flexors and extensors were recorded. The highest peak torque obtained from the three trials was used for analysis.¹³ Isokinetic dynamometry is widely used in individuals with neurological conditions, including stroke, to quantify trunk muscle strength objectively and to evaluate functional impairment and rehabilitation outcomes.¹⁴

Gait Function: Gait function was evaluated using the Tinetti Performance-Oriented Mobility Assessment (POMA), which consists of two subscales: gait and balance. This test assesses various aspects of walking and balance, including step initiation, step length and height, symmetry, continuity, trunk stability, and sitting balance. Participants were allowed to use their customary walking aids (e.g., cane or walker) during the assessment when required, in accordance with the test's standard administration procedures. Administration typically takes 5–10 minutes and requires access to basic equipment, including a stopwatch, a chair, a 5-pound (≈2.5 kg) object, and a 15-foot (≈5 m) walking space. Each item is rated on a 0–2 ordinal scale, where lower scores indicate greater impairment, with a maximum total score of 28.¹⁵ In the present study, the total POMA score was used in the analysis to represent overall mobility performance, including both gait and balance components.

Power Analysis

In the absence of prior data specific to this population, a moderate effect size was assumed in accordance with Cohen's guidelines for behavioral and clinical research.¹⁶ An a priori power analysis for correlation analysis was performed using G*Power software (version 3.1), with an assumed effect size of $r = 0.50$, an alpha level of 0.05, and a statistical power of 80%. Based on these parameters, the minimum required sample size was calculated as 29 participants. Accordingly, a total of 30 geriatric individuals with chronic stroke were included in the study.

Ethical Approval

The Ethics Committee of İstanbul Atlas University approved this study (Date: 22.12.2025, Decision No: 11/39).

Statistical Analysis

Statistical analyses were performed using SPSS v26. Normality was tested using the Shapiro–Wilk test. Data were presented as mean

± standard deviation (SD) or percentage (%). The relationships between spasticity, trunk muscle strength, and gait performance were analyzed using Pearson's correlation coefficient [®]. Variables that showed significant correlations with gait performance were subsequently entered into a multiple linear regression analysis to determine independent predictors of gait function. Statistical significance was set at *P* < .05.

Reporting Guidelines

This cross-sectional observational study employed convenience sampling and was reported in accordance with the STROBE guidelines.

Results

A total of 30 individuals with chronic hemiplegia were included in the study (Table 1). The mean age of the participants was 72.06 ± 4.76 years. Of the participants, 11 (36.7%) were women, and 19 (63.3%) were men. The mean BMI was 25.52 ± 2.49 kg/m². All participants were right-hand dominant. The mean time since stroke onset was 52.5 ± 36.5 months, and among the participants, 18 had ischemic stroke while 12 had hemorrhagic stroke. The affected side was the right in 11 participants (36.7%) and the left

Table 1. Sociodemographic and Clinical Data of Stroke Survivors

Hemiplegia (n = 30)	Mean ± SD or n (%)
Age, y	72.06 ± 4.76
Gender	
Woman	11 (36.7)
Man	19 (63.3)
Height, cm	170.23 ± 8.34
Weight, kg	74.33 ± 11.83
BMI, kg/m ²	25.52 ± 2.49
Time since the onset of stroke, mo	52.5 ± 36.5
Type (I/H)	18/12
Dominant side	
Right	30 (100)
Left	-
Affected side	
Right	11 (36.7)
Left	19 (63.3)
MAS (knee)	1.73 ± 0.82
MAS (hip)	1.63 ± 0.71
MAS (ankle)	2.03 ± 0.76
Trunk strength (flexion), Nm	158.06 ± 15.02
Trunk strength (extension), Nm	90.22 ± 17.18
POMA	20.70 ± 2.18

Results were presented as mean ± standard deviation (SD) or as percentages (%). cm, centimeter; kg, kilogram; BMI, Body Mass Index; I, Ischemic; H, Hemorrhagic

Table 3. Multiple Linear Regression Analysis

Variables	B	Standardized error of B (95% CI)	Standardized beta coefficient	P value	R ²
Variables	391.454	341.50-441.39		.001	0.605
MAS (Knee)	1.061	0.439-1.683	0.454		
MAS (Hip)	2.029	-2.596-3.653	0.412		
MAS (Ankle)	3.964	1.648-6.280	0.585		

MAS, Modified Ashworth Scale; **P* < .05.

in 19 participants (63.3%).

A correlation analysis was performed to examine the relationships among lower-extremity spasticity, trunk muscle strength, and gait performance. According to the results as shown in Table 2, the POMA score was negatively correlated with spasticity levels of the knee (*r* = −0.691, *P* < .001), hip (*r* = −0.425, *P* = .019), and ankle (*r* = −0.825, *P* < .001) as measured by the Modified Ashworth Scale. In contrast, there was no significant correlation between gait score and trunk flexor (*r* = 0.256, *P* = .172) or extensor muscle strength (*r* = 0.227, *P* = .228).

Multiple linear regression analysis was conducted to identify independent predictors of gait function (Table 3). The overall regression model was statistically significant (*P* = .001) and explained 60.5% of the variance in POMA scores (*R*² = 0.605). Among the variables included in the model, ankle spasticity (*β* = 0.585, *P* < .05) emerged as the strongest independent predictor of gait performance, followed by hip (*β* = 0.454) and knee spasticity (*β* = 0.4122).

Discussion

This study investigated the extent to which lower extremity spasticity and trunk muscle strength predict gait performance in geriatric individuals living with chronic stroke. The results demonstrated significant negative correlations between gait function and spasticity levels of the knee, hip, and ankle joints, indicating that higher muscle tone is associated with poorer gait performance. Trunk muscle strength did not show a significant correlation with gait performance and was therefore not included as a predictor.

Spasticity is a common sequela of stroke. According to a systematic review, approximately 25.3% of stroke survivors develop spasticity, and this rate increases up to 39.5% in patients with paresis following a first-ever stroke.¹⁷ Spasticity after stroke prominently impacts gait performance, thereby limiting patients' independence and overall functional mobility. Recent evidence also suggests that chronic spasticity contributes to secondary biomechanical changes, including muscle shortening and joint stiffness, which may further

Table 2. Correlation Between Lower Extremity Spasticity Score and Trunk Muscle Strength in Stroke Survivors

	POMA	
	<i>r</i>	<i>P</i> value
MAS (Knee)	-0.691	< .000*
MAS (Hip)	-0.425	.019*
MAS (Ankle)	-0.825	< .000*
Trunk Flexor Muscle Strength	0.256	.172
Trunk Extensor Muscle Strength	0.227	.228

MAS, Modified Ashworth Scale; POMA, Tinetti Performance-Oriented Mobility Assessment **P* < .05.

exacerbate gait impairments over time.¹⁸

Although studies have demonstrated that lower-limb spasticity adversely affects balance, gait performance, and fall risk in post-stroke individuals, the extent of these impairments may vary with the severity of spasticity.⁵ Among the participants in this study, while the knee and hip exhibited mild to moderate spasticity based on the MAS, ankle spasticity was comparatively higher, approaching the upper end of moderate severity. This pattern was consistent with the regression analysis, in which ankle spasticity demonstrated the strongest independent association with gait performance, followed by hip and knee spasticity. Our findings align with those of Freire et al.,¹⁹ who reported that higher MAS scores, particularly in the ankle plantar flexors, are associated with reduced walking ability and poorer functional mobility in individuals with chronic stroke. In the recent observational study examining functional performance across spasticity severity levels using balance and gait ability tests, only gait tests involving directional changes differentiated individuals with higher ankle plantar flexor spasticity from those without.²⁰ This aligns with our findings, highlighting that distal spasticity primarily affects gait-related parameters.

Trunk muscle impairment is a frequent issue following a stroke, resulting in difficulties with everyday activities, balance, and independent walking.²¹ Earlier studies have demonstrated that trunk-related measures are closely associated with balance, gait, and overall functional ability in individuals with post-stroke hemiplegia.^{12,22} In addition, trunk muscle mass decreases with age; therefore, assessing and addressing trunk function within rehabilitation is considered particularly important for geriatric individuals living with stroke.

While the trunk plays a crucial role in maintaining stability and gait after stroke, most research has focused on trunk control rather than muscle strength. Evidence on the relationship between trunk strength and gait is limited in patients with stroke; however, since muscle strength is a key component of trunk control, it is often assumed that greater trunk strength contributes to better walking performance.²³ In the present study, however, no significant correlation was found between gait performance and either trunk flexor or extensor strength. This finding contrasts with earlier research suggesting that greater trunk muscle strength is associated with improved gait speed, balance, and overall functional mobility in individuals with stroke.^{12,24} One possible explanation for this contradiction may lie in the advanced age and chronic stage of our sample, where long-term compensatory strategies and neuromuscular adaptations could have diminished the contribution of trunk muscles to gait control. Moreover, our participants demonstrated relatively high trunk torque values compared with those in previous studies,^{13,22,25} suggesting a possible “ceiling effect,” that is, limited variability at the upper range of strength scores, which may have masked potential correlations. Another possible explanation is that, in the chronic phase of stroke, gait performance depends more strongly on distal factors such as spasticity, balance control, and sensory feedback rather than on proximal trunk strength alone. Indeed, our results showed that spasticity of the ankle, hip, and knee joints—particularly at the ankle—was a more powerful predictor of gait outcomes. Taken together, these findings suggest that while trunk function remains essential for maintaining postural stability and balance, its direct contribution to walking ability in geriatric individuals with chronic stroke may be overshadowed by the effects of distal motor impairments and long-term neuromuscular adaptations.

Limitations

This study has some limitations. The absence of a control group limited our ability to compare and interpret the isokinetic strength values in a broader clinical context. In addition, trunk function was evaluated solely through muscle strength measurements, and no specific assessment of trunk control or postural coordination was included; therefore, the complex contribution of trunk control to gait performance may not have been fully captured. Lastly, gait performance was evaluated using a clinical observational scale (POMA) rather than objective instrumented gait analysis, which may provide more detailed information about walking performance.

Conclusion

This study demonstrates that lower extremity spasticity, particularly at the ankle joint, is a significant predictor of gait performance in geriatric individuals with chronic stroke. In contrast, trunk muscle strength did not independently contribute to walking ability in this population. These findings suggest that distal motor impairments more strongly influence gait performance in the chronic and geriatric stroke populations than proximal trunk strength does. Targeting lower-limb spasticity may therefore be a key focus of rehabilitation strategies aimed at improving gait function.

Declarations

Animal and Human Rights Statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments, or comparable ethical standards.

Informed Consent

All participants provided written informed consent before data collection.

Data Availability

The datasets used and/or analyzed during the current study are not publicly available due to patient privacy reasons, but are available from the corresponding author on reasonable request.

Conflict of Interest

The authors declare no conflict of interest.

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Author Contributions (CRediT Taxonomy)

Conceptualization: Ş.Ö., M.K.

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Validation: M.K.

Formal Analysis: Ş.Ö., M.K.

Investigation: Ş.Ö.

Data Curation: Ş.Ö., M.K.

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Writing – Review & Editing: Ş.Ö., M.K.

Visualization: M.K.

Supervision: M.K.

AI Usage Disclosure

The authors declare that no AI-assisted technologies were used.

Abbreviations

BMI: Body mass index

CT: Computed tomography

FAC: Functional ambulation classification

MAS: Modified ashworth scale

MRI: Magnetic resonance imaging

POMA: Performance-oriented mobility assessment

SD: Standard deviation

SPSS: Statistical package for the social sciences

STROBE: Strengthening the reporting of observational studies in epidemiology

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