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Impact of an articulated knee orthosis on mobility and postural control in stroke patients: A gerontechnology perspective

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Abstract

Background: Recent advances in gerontechnology have provided benefits for both healthy and pathological aging. Certain neurological conditions, such as stroke, can diminish patient independence by impairing mobility and postural control.
Objective: To investigate whether an articulated knee orthosis can enhance mobility and postural control in stroke patients.
Method: Fifty hemiparetic participants with a history of ischemic stroke (mean age: 59.2 ± 7.6 years; time since stroke: 50.8 ± 32.4 months) participated in walking and standing tasks, with and without an articulated knee orthosis on their hemiparetic side. Mobility was assessed using the timed get-up-and-go test, which included measures of time and number of steps. Postural control was evaluated using the K-Force Plate system and included measures of center of pressure, total displacement, frontal and lateral sway, and weight distribution. Paired comparisons were used to assess differences in outcomes with and without knee orthosis. Significance was set at 5%. Effect sizes (ES) were reported.
Results: The use of an articulated knee orthosis significantly improved mobility of the participants (p = 0.004; ES = 0.466 for time and p = 0.003; ES = 0.441 for number of steps). In terms of postural control, only lateral sway showed significant improvement (p = 0.031; ES = 0.189).
Conclusion: The use of an articulated knee orthosis significantly improved mobility in participants with a history of stroke. In contrast, among all postural control variables, only lateral sway showed improvement. Gerontechnology should further explore devices capable of enhancing postural control more effectively in stroke patients.

Keywords: stroke, aged, mobility limitation, postural balance, assistive technologies

Introduction

Gerontechnology is a scientific field that explores technology as an integrated tool in people's lives (Moreno et al., 2024). Through a creative and multidisciplinary approach, gerontechnology seeks solutions to the challenges posed by human aging (Micera et al., 2008; Huang & Oteng, 2023).

The use of assistive devices in gerontechnology has garnered attention from researchers, healthcare professionals, patients, family members, and caregivers. Efforts to promote greater independence in older adults have shown positive results, contributing to the integration of gerontechnology into assistance policies (Chen et al., 2022; Piau et al., 2014; Haufe et al., 2019).

One of the challenges gerontechnologists face is the creation of innovative designs for products and resources that meet the diverse needs of older adults. For example, the needs of an older adult with Alzheimer's disease, where the primary focus is on cognitive support, differ from those of an older adult with Parkinson's disease, where the emphasis is on motor functions (Ogbodo et al., 2022; Aranda et al., 2021; Ben-Shlomo et al., 2024; Kwok et al., 2021). The heterogeneity of human aging, compounded by various clinical conditions, poses a challenge to effectively integrate technology into people's lives (Rießenberger & Fischer, 2023; Haufe et al., 2019).

Stroke is one of the conditions that most affects the independence of older adults (Neil, 2023). It is characterized by acute disruption of blood circulation leading to alterations in blood flow, hemorrhages, embolisms, and thrombosis. Older adults who experience stroke often face motor impairment, sensory dysfunctions, and cognitive impairment, all of which can significantly affect their quality of life (Verstraeten et al., 2020; Bolognini et al., 2016; Huang et al., 2022).

Stroke symptoms vary according to the affected brain area. The vascular system is complex and includes an anastomosis called the Polygon of Willis, which ensures blood flow to various arteries. A commonly affected artery during stroke is the middle cerebral artery, which supplies blood to the precentral and postcentral gyri, which are responsible for primary motor and somatosensory functions, respectively. When these areas are compromised, hemiplegia and hemianesthesia occur (Finkelsteyn et al., 2019). Damage to other brain areas, known as the secondary motor and sensory cortices, can result in more complex symptoms, such as apraxia and agnosia (Christofoletti & Moraes, 2025). These conditions impair the ability to plan motor tasks and interpret sensory stimuli (Timpert et al., 2015; Barrett, 2021).

Regardless of the specific artery affected, stroke patients commonly experience mobility and postural control issues. As stroke is more prevalent with advancing age, older adults affected by stroke may face challenges stemming from both the vascular event and the effects of aging (Jia et al., 2019). Previous studies have shown that aging is associated with various micro- and macrostructural changes in the brain, such as reduced cortical thickness, decreased gray matter volume, and alterations in white matter, all of which are linked to decline in physical function (Turrini et al., 2023; Zheng et al., 2019; Demnitz et al., 2017).

In alignment with the goal of promoting healthy aging, older adults are now engaging in more physical activity than in the past. Physical therapists and other motor function specialists, as physical education professionals, play an important role when motor functions are compromised in older adults (Costa et al., 2023; Ferreira et al., 2022; de Lima & Christofoletti, 2020). In some cases, assistive devices are used to improve functional performance in older adults affected by stroke (Ota et al., 2018).

Stroke patients often exhibit considerable variations in gait, with knee hyperextension emerging as a sequela of the chronic phase of the dysfunction (Okada et al., 2024). Muscle tone alterations caused by ischemic and hemorrhagic events contribute to these changes. In the acute phase, hypotonia is typically present, while in the chronic phase, patients often experience hypertonia and difficulty contracting the muscles correctly. Knee hyperextension is particularly detrimental because it results in abnormal knee movement that can lead to ligament and meniscus injuries, causing pain, deformities, and instability (Li et al., 2023; Aderibigbe et al., 2020).

To help preserve knee function, orthoses have been prescribed to stroke patients. Articulated knee orthoses are used to prevent knee hyperextension, improve patients' confidence while walking, and enhance their sense of security. Previous studies have demonstrated the benefits of orthoses in stroke (Chen et al., 2023; Ohtsuka et al., 2023; Johnston et al., 2021). However, evidence on the effectiveness of knee orthoses remains limited, highlighting the need for further research (O'Connor et al., 2016).

In light of this review, this study aimed to evaluate the benefits of an articulated knee orthosis on mobility and postural control in patients with stroke. We hypothesized that using an articulated knee orthosis would lead to better outcomes in terms of mobility (improving time and number of steps on specific walking tasks) and postural control (improving center of pressure, total displacement, frontal and lateral sway, imbalance speed, and weight distribution).

Methods

This cross-sectional study was conducted with 50 participants, 22 women. The participants were recruited in the city of Campo Grande, Brazil. All individuals provided written informed consent prior to assessment. Ethical approval was obtained from the Institutional Research Ethics Committee (protocol #6.432.059).

Recruitment was conducted through direct contact with potential participants and social media. The inclusion criteria were adults aged 50 years or older, of any sex, religion, race, or educational level, and who were presenting with hemiparesis and hypertonia in the chronic phase of the stroke. Exclusion criteria included individuals who were unable to attend the data collection center, those who were unable to walk independently, and those with concomitant neurological or psychiatric disorders.

In total, 123 individuals were assessed for eligibility. However, the final sample size was reduced to 50 participants because of difficulties of some individuals in achieving independent gait (59 patients excluded) and the presence of concomitant neurological disorders (14 patients excluded).

To assess whether the sample of 50 participants was sufficient to control for type I and type II statistical errors, we calculated the required sample size. Using an α error probability of 0.05, a power of 0.80, and effect sizes of 0.53 and 0.55 (based on prior studies highlighting the benefits of orthoses for mobility and postural control in stroke patients) (Yamamoto et al., 2022; Chen et al., 1999), we identified that a minimum of 32 participants would be required. Based on this analysis, the final sample size of this study exceeded the threshold by 56.2%.

The participants had a mean age of 59.2 ± 7.6 years and a time since stroke of 50.8 ± 32.4 months. All participants suffered ischemic event and the lesion were located mainly on the superior parietal lobule (pre- and postcentral gyrus region). All participants presented an independent walking. *Table 1* provides details on individual characteristics, including sex, age, weight, height, body mass index, time since stroke, and the side of hemiparesis.

Methodological procedures
The methodological procedures are described in accordance with the STROBE Statement checklist. Participants performed walking and static tests with and without an articulated knee orthosis. The same orthosis was used for all the participants.

We selected an articulated knee orthosis with a height of up to 50 cm, a circumference of up to 38 cm, and an adjustable knee range designed to prevent hyperextension. The orthosis was positioned on the participant's hemiparetic side, with the extension fixed at 0° to prevent knee hyperextension, while flexion remained unrestricted, allowing movement of up to 140°. All participants were able to adjust the orthosis for optimal comfort. Additionally, the orthosis featured lateral struts to enhance stability during movement. *Figure 1* illustrates the knee orthosis used in this study.

The efficacy of the knee orthosis while walking was used during the timed get-up-and-go test (TUG) (Podsiadlo & Richardson, 1993). This test measures the time and number of steps necessary to get up from a chair, walk three meters, return, and sit down on the same chair. A longer time to perform the task and a greater number of steps indicate poorer mobility. To evaluate static upright postural control, the participants underwent a test on a force platform (K-Force®, Kinvent, Montpellier, France). The test was performed barefoot, with participants instructed to maintain their standing position on the platform for 30 seconds. The following variables were assessed: frontal and lateral sway (cm), total displacement (cm), center of pressure (cm2), imbalance speed (cm/s), and weight bearing (%). Higher values of these variables indicate poorer postural control performance.

All assessments were conducted at the CER-APAE Rehabilitation Center (Campo Grande, Brazil) under controlled conditions, ensuring consistency in floor regularity, lighting, and temperature. The order of the tests (with and without the knee orthosis) was randomized. Participants selected opaque envelopes containing information about the assessment order to ensure unbiased test sequencing. The researchers provided a 20-minute familiarization period with the orthosis prior to the assessments. None of the participants had previously used any knee orthosis.

Statistical analysis
Statistical analysis was performed in several steps. First, we assessed whether the data met the parametric assumptions. For variables that followed a normal distribution, the results are presented as mean and standard deviation. For variables that did not meet normality assumptions, the data are presented as median and interquartile range. Then, to analyze the effect of the knee orthosis on mobility and postural control, Student t-tests and Wilcoxon W-tests were applied for parametric and non-parametric data, respectively. When significant differences were found, effect sizes were reported. For all analyses, significance was set at 5%.

Results

One hundred twenty-three participants were recruited. Seventy-three patients were excluded because they did not meet the eligibility criteria. A total of 50 participants completed the study. *Table 2* presents the data for each variable measured during the TUG test, along with its respective analyses. The results confirm the benefits of knee orthosis, particularly in reducing both the completion time and the number of steps taken by participants. Inter-patient factors, such as age, sex, mobility levels, and extent of impairment, had no significant effect on the results.

Table 3 presents the data for each variable measured during the postural control test. Unlike mobility, where both time and number of steps improved with the knee orthosis use, only lateral sway showed benefits from orthosis use. The remaining variables did not show significant differences with the knee orthosis. Inter-patient factors, such as age, sex, mobility, and extent of impairment had no significant effect on the results.

Discussion

Stroke patients frequently face mobility challenges and postural instability, which can significantly affect their daily activities and overall quality of life. This study aimed to assess the effects of an articulated knee orthosis on mobility and postural control in stroke patients. Our findings

Table 1. Anthropometric and clinical characteristics of the participants

Variables	Values	95% Confidence interval
Sample size, n (men:women)	28:22	—
Age, yrs	59.2 (7.6)	57.0 – 61.4
Weight, Kg	77.2 (14.1)	73.2 – 81.2
Height, m	1.7 (1.0)	1.6 – 1.7
Body Mass Index, Kg/m²	27.8 (4.9)	26.4 – 29.2
Time since stroke, months	50.8 (32.4)	41.6 – 60.1
Hemiplegic side, n (right:left)	22:28	—

demonstrated substantial improvements in mobility with the use of knee orthosis, along with modest gains in postural control, particularly in reducing lateral sway. Other aspects of postural control showed no significant changes with the knee orthosis. These results have important implications for clinical practice.

The profiles of stroke patients are highly diverse. Although stroke predominantly affects older adults, growing levels of sedentarism, stress, presence of metabolic diseases and hypertension contribute to an increase in cases among younger individuals (Retho et al., 2023; Lasek-Bal et al., 2018). Given our objective to examine this study from a gerontechnology perspective, we focused our sample on individuals aged 50 years and older, recognizing that participants were either already older adults or nearing the age of 60.

Figure 1. Knee orthosis used in this study

Previous studies have demonstrated the benefits of knee orthoses in stroke patients during rehabilitation (Ito et al., 2024; Iida et al., 2017; Geerars et al., 2022). Our study differs by focusing on the use of the knee orthosis as a wearable device for continuous use, rather than as part of a rehabilitation program. Ito et al. (2024) found that gait training with a knee orthosis was more effective in improving walking performance than training without it. While this finding is valuable, our research specifically investigated the benefits of knee orthosis used independently, without being coupled with a rehabilitation protocol.

Mobility impairments are common in stroke patients. A study of 197 patients found that mobility was the most commonly aggravated issue within six months after stroke (Im et al., 2020). As gait disturbances significantly affect the independence and quality of life of stroke patients, finding ways to improve this aspect is crucial (Rejnö et al., 2019; Aali et al., 2020).

Stroke affects various aspects of gait, including the biomechanical, spatiotemporal, and kinetic elements. Together, these factors make gait a complex and significant issue in stroke patients (Balaban & Tok, 2014). Observational gait analysis is the most commonly used method for evaluating gait in stroke. Several instruments and devices can assist professionals in the interpretation of gait disturbances. However, only validated instruments should be used as they accurately assess the intended parameters and contribute to the integration of research and clinical practice (Ferrarello et al., 2013). In this study, we used the TUG test to assess gait performance because it showed high agreement between the test-retest measurements and good sensitivity to enable the detection of clinical changes (Flansbjer et al., 2005).

The results presented in Table 1 show that the use of knee orthosis led to a reduction in both the time required to complete the TUG test and the number of steps taken. This indicates that, with the knee orthosis, the participants were able to perform the test more efficiently, with a shorter time and fewer steps. This finding suggests that knee orthosis improves patients' confidence and safety while walking on a regular surface. In spite of multiple factors contributing to gait instability in stroke patients, it appears that knee hyperextension, stabilized by the articulated orthosis used in this study, plays a key role.

Although participants showed improved performance with the knee orthosis, their scores on the TUG test remained above the cutoff values established for the instrument. For older adults, a cutoff of 12 seconds is considered a reliable

Table 2. Impact of knee orthosis on mobility

Mobility (TUG test)	Orthosis		Mean difference	95% C.I.		p	Effect size
	off	on		Lower bound	Upper bound		
Time, s	29.1 (17.7)	25.4 (20.1)	1.7	0.5	3.2	0.004	0.466
Steps, n	28.7 (11.5)	26.5 (11.1)	2.1	0.7	3.5	0.003	0.441

predictive benchmark (Alexandre et al., 2012). This finding suggests that while knee orthoses enhance mobility in stroke, they should not be considered as a substitute treatment for rehabilitation exercise protocols. Moreover, the current finding indicates that the design of knee orthoses still needs to be improved, as it does not promote full recovery of mobility, thus representing an opportunity for innovation.

Most studies on knee orthoses have primarily focused on their effects during walking. Given that knee hyperextension affects the femoral and intercondylar cartilages in stroke patients and that joint instability can significantly impair balance, we expected to find more studies on the effects of knee orthoses on postural control (Korkusuz et al., 2024; O'Connor et al., 2016). However, our search yielded a limited number of studies in this area. We attribute this pattern to the likelihood that patients with stroke perceive limitations in mobility as more impactful than challenges in static balance. Mobility restrictions are often linked to increased fear and anxiety, which can reduce self-confidence and independence (McCaughan et al., 2019).

Apart from a reduction in lateral sway, the knee orthosis did not provide significant benefits for postural control. This finding was unexpected, as we had hypothesized that stabilizing the hemiparetic knee would enhance static stability. Although the improvement in lateral sway was statistically significant, the effect of the orthosis was minimal, showing only a 0.2 cm difference between assessments. Given this small magnitude, we believe the difference is not clinically relevant. Other postural control variables exhibited only minor, non-significant changes. Overall, our findings suggest that the knee orthosis is more effective in enhancing dynamic rather than static motor aspects, though further studies are needed to confirm this.

A possible explanation for the greater benefits of knee orthosis on gait compared to postural control may be related to knee biomechanics. The knee has a locking mechanism that enables a person to stand for long periods with minimal energy expenditure. When the leg is fully extended, the femur undergoes a slight medial rotation on the tibia, helping to maintain an upright posture without excessive fatigue. Since the knee's bone and ligaments are generally preserved after a stroke, it is possible that the knee orthosis is more effective during walking, as this activity induces greater instability than standing (Okada et al., 2024). Future research should investigate whether postural control is a significant aspect in patients with stroke. If so, gerontechnology could further explore devices specifically designed to improve static balance, potentially offering greater benefits.

Limitations

We acknowledge three limitations of this study. First, the findings are specific to relatively younger stroke patients who experienced an ischemic event and are in the chronic phase of the disease. Since hemorrhagic strokes tend to be more severe than ischemic strokes, the results may not be generalizable to that population. Second, all assessments were conducted using a single type of articulated knee orthosis. Given the wide range of knee orthoses available today, which vary in size, structure, and functionality, future studies should examine the effects of different orthosis models. Finally, stroke patients often experience instability across multiple joints (Sheffler and Chae, 2015). Our findings are limited to an orthosis that stabilizes only the knee, without directly addressing the foot, ankle, or hip joints.

Table 3. Impact of knee orthosis on postural control

Postural control (K-Force platform)	Orthosis		Mean difference	95% C.I.		*p*	Effect size
	Off	On		Lower bound	Upper bound		
Center of pressure, cm²	15.7 (13.2)	14.2 (14.1)	1.8	-6.7	49.7	0.144	NS
Total displacement, cm	39.1 (17.5)	38.3 (17.4)	0.8	-21.9	39.2	0.575	NS
Imbalance speed, cm/sec	1.3 (0.8)	1.2 (0.7)	0.1	-0.7	1.5	0.457	NS
Frontal sway, cm	1.6 (0.6)	1.5 (0.6)	0.1	-0.5	2.6	0.204	NS
Lateral sway, cm	1.2 (0.6)	0.8 (0.8)	0.2	0.2	3.0	0.031	0.189
Weight bearing on the left side, %	49.7 (16.2)	50.2 (15.3)	0.5	-1.7	0.6	0.340	NS
Weight bearing on the right side, %	51.1 (24.6)	51.7 (21.7)	0.6	-0.5	1.8	0.311	NS

NS: Non-significant effect.

Clinical implications

Despite its limitations, this study offers valuable clinical insights for stroke patients. The findings suggest that using an articulated knee orthosis improves gait. However, readers should note that these results are based on a short observation period. Further research is needed to determine whether similar benefits are sustained in the long term.

Conclusions

An articulated knee orthosis showed greater improvement in mobility than in postural control in hemiparetic stroke patients. Although mobility gains are valuable, they should not replace a comprehensive rehabilitation process with a specialist in neurological disorders. Gerontechnology should continue to explore devices that can specifically enhance postural control in stroke patients.

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Conflict of interests: All the authors declare that there is no conflict of interest.

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