Saúde e Pesquisa

Promoção da Saúde
DOI: 10.17765/2176-9206.2023v16n4.e11630

Changes in gait angular kinematics of hemiparetic patients After Cerebrovascular Accident

Alterações na cinemática angular da marcha de pacientes hemiparéticos após Acidente Vascular Encefálico

Stéfanie Defaveri Ciotta[1], Luana Zanardi Lipreri Rubert[2], Laura Buzin Zapparoli[3], Fernanda Cechetti[4], Leandro Viçosa Bonetti[5], Raquel Saccani[5]

[1] Master candidate of Post-Graduation Program in Health Sciences, Universidade de Caxias do Sul (UCS), Caxias do Sul (RS), Brazil.
[2] Physiotherapy. Universidade de Caxias do Sul (UCS), Caxias do Sul (RS), Brazil.
[3]Physiotherapy student. Universidade de Caxias do Sul (UCS), Caxias do Sul (RS), Brazil.
[4] Department of Physioterapy, Professor of Post-Graduation Program in Rehabilitation Sciences, Universidade Federal de Ciências da Saúde de Porto Alegre (UFCSPA), Porto Alegre (RS), Brazil.
[5] Department of Physiotherapy, Professor of Post-Graduation Program in Health Sciences, Universidade de Caxias do Sul (UCS), Caxias do Sul (RS), Brazil.

***Corresponding author:** Raquel Saccani– *E-mail*: rsaccani@ucs.br

Received in march 21, 2023
Accepted on may 21, 2023

ABSTRACT
This study aimed to analyze changes in gait angular kinematics of adults with hemiparesis after cerebrovascular accident (CVA). The sample consisted of 17 post- cerebrovascular accident (CVA) patients; and, for gait evaluation, it used a three-dimensional gait trajectory capture system. As for healthy and affected limbs, the variables studied were: speed, maximum angles of flexion, and extension of the hip and knee. For the comparisons between the members, the study used the *t*-paired test; and, for comparisons with normal values, it used the *t* test for a sample, whereas, as a decision criterion, the significance level $p \leq 0.05$. The results showed, in the comparison between the limbs, significant differences in flexion (0.001) and knee extension (0.05). In the comparison between the affected limb and the healthy one, there is a significant difference in knee flexion angles (<0.000) and hip extension (0.004). Patients with post-CVA hemiparesis present changes in gait angular kinematics when the affected limb is compared with the healthy limb and with normal values. The study observed a predominantly flexor gait pattern, with a considerable variability among the evaluated patients.

Keywords: Gait. Stroke. Hemiparesis.

RESUMO
O objetivo deste estudo foi analisar as alterações na cinemática angular da marcha de adultos com hemiparesia após acidente vascular encefálico (AVE). A amostra foi composta por 17 pacientes pós-AVE; e, para a avaliação da marcha, foi utilizado um sistema de captura da trajetória tridimensional da marcha. Quanto aos membros sadio e afetado, as variáveis estudadas foram: velocidade, ângulos máximos de flexão e extensão do quadril e joelho. Para as comparações entre os membros, foi utilizado o teste *t* pareado; e, para as comparações com valores normais, o teste *t* para uma amostra, considerando, como critério de decisão, o nível de significância $p \leq 0,05$. Os resultados demonstraram, na comparação entre os membros, diferenças significantes na flexão (0,001) e extensão de joelho (0,05). Já na comparação entre o membro afetado e o sadio, destaca-se a diferença significante das angulações de flexão de joelho (<0,000) e extensão de quadril (0,004). Os pacientes com hemiparesia pós-AVE apresentam alterações na cinemática angular da marcha quando comparado o membro afetado com o sadio e com os valores da normalidade. Observou-se um padrão de marcha predominantemente flexor, com grande variabilidade entre os pacientes avaliados.

Palavras-chave: Marcha. Acidente Vascular Encefálico. Hemiparesia.

INTRODUCTION

Cerebrovascular accident (CVA) is a distinguished health problem in the world population and is the most common cause of motor and cognitive disabilities in the world[1]. Specifically in Brazil, the consequent limitations of CVA affect approximately 600 thousand people[2]. Clinical signs are defined by the injured cortical area and the extent of the damage, affecting the functionality of individuals[3]. Among the most common impairments, spastic hemiparesis stands out, characterized by decreased muscle strength on the contralateral side of the brain injury[4]. Spasticity is considered a common symptom in hemiparetic patients, and 42% of individuals with cerebrovascular accident develop it in the first six months after injury[5].

Spasticity causes increased muscle tension and hyperexcitability of reflexes, causing involuntary contractions of the muscles, which impairs the ability to perform coordinated movements and impacts the execution of activities of daily living[6]. This increase in tone also provokes critical changes in the gait pattern of patients, changing their functionality and quality of life[7]. Different studies have already described the changes in linear kinematics: low speed, shorter step length, shorter cadence, longer step width, shorter cycle length, longer duration of double support, with longer gait cycle duration[8-11].

Concerning the angular characteristics of the gait, although little emphasized, changes in angular variables are mentioned in some works[8,10,12-15]. Since the vast majority of hemiparetic patients aim to improve their gait pattern, it is relevant to understand the angular changes that occur during hemiparetic locomotion so that it is possible to properly direct the rehabilitation process, as well as the prescription of orthoses and auxiliary devices. However, few articles specifically address angular gait changes, especially if they consider the three-dimensional laboratory evaluation. Therefore, the main objective of this study was to analyze the changes in the angular kinematics of gait of adults with hemiparesis after CVA and compare the affected side with the healthy and with a normality.

METHODOLOGY

This research is an observational, analytical study with a cross-cutting approach[16]. It is part of a project approved (protocol 4,812,281) by the Ethics and Research Committee of the Federal University of Health Sciences of Porto Alegre (Porto Alegre, State of Rio Grande do Sul, Brazil) and conducted following the legal provisions of Resolution Nº 510, of April 2016, of the National Health Council, which approves the guidelines and regulatory standards for research involving human beings. The place of this study was the Laboratory of biomechanical analysis of Human Movement of the Clinical Center of the University of Caxias do Sul (*Laboratório de Análise Biomecânica do Movimento Humano - Centro Clínico da Universidade de Caxias do Sul* - CECLIN-UCS).

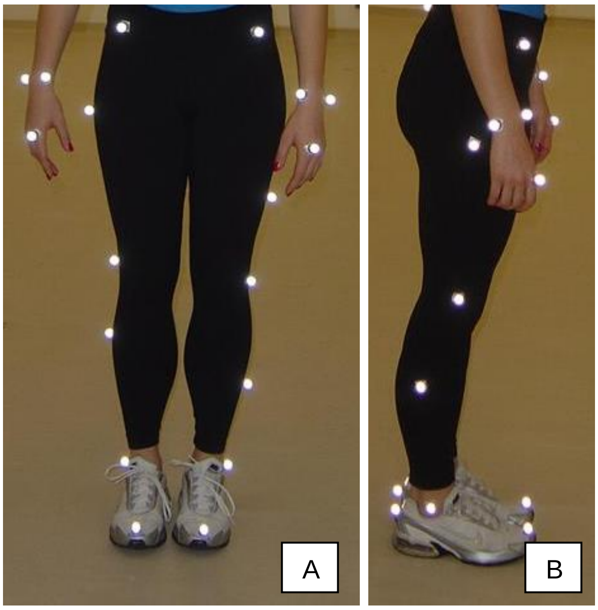
The sample consisted of 17 patients, selected through reading medical records from CECLIN-UCS. The study took place between September 2020 and December 2022, and determined the sample intentionally and not probabilistically, for convenience, according to the number of patients registered in the service. Inclusion criteria were: a) presence of hemiparesis after CVA; b) age between 20 and 59 years; C) signing of the Informed Consent Form (ICF); d) functional capacity to complete the gait analysis. Exclusion criteria were: a) cognitive changes that prevented the understanding of the ICF and the performance of gait analysis; b) alteration of vital signs on the day of collection; c) previous history of other neurological or musculoskeletal diseases.

Initially, researchers requested the Ceclin Physical Therapy Clinic to provide access to the site and the patients' medical records for sample selection. They collected information regarding personal data, clinical diagnosis, and main clinical and functional characteristics in the medical records. With the selected sample, the participants received the schedules for data collection in the gait laboratory.

Gait analysis was performed in the Laboratory of biomechanical analysis of Human Movement, from CECLIN-UCS, located in Block 70 of the University of Caxias do Sul. It contains a system and protocol for capturing kinematic and kinetic gait data. For capturing the three-dimensional trajectory of the gait, the study used a cinemetrics system with seven integrated cameras (VICON MX systems, Oxford Metrics Group, UK). Kinematic data were collected at a sampling rate of 100 Hz.

On the day of collection, the participants signed the Informed Consent Form and answered a questionnaire to characterize the sample, considering the personal data, history of current and previous pathology, information about the injury, and how long have they been doing physiotherapy. The study used the Functional Independence Measurement (FIM) scale, translated and validated in Brazil[17], to evaluate the functionality. It assesses individuals quantitatively regarding the care demanded by a person to perform motor and cognitive tasks of daily life. The evaluated tasks are divided into the domains: self-care, transference, locomotion, sphincter control, communication, and social cognition. Each item is evaluated with a score from 1 (total dependence) to 7 (total independence), and the total score ranges from 18 to 126[17]. In addition, vital signs were measured to ensure clinical stability during collections, body weight, and height of each individual. For this, the research used a stethoscope, sphygmomanometer, oximeter, thermometer, and scales.

After the initial information collected, the patients proceeded to the gait assessment, following the Laroche protocol[18]. To adapt the participant to the gait assessment protocol, an eight-meter walk in a straight line, at a self-selected speed, was requested at the site intended for gait collection in the laboratory. Each participant memorized the number of steps and the rhythm necessary to make contact on the platform, sometimes with the whole right foot and sometimes with the whole left foot. After familiarization, reflective markers were affixed to the following anatomical points: anterosuperior iliac spines, posterosuperior iliac spines, mediolateral portions of the femurs, mediolateral portions of the knees, mediolateral portions of the tibias, lateral malleolus of the ankles, centroposterior portions of the calcaneus, and dorsal aspect of the second metatarsals (Figure 1).



Legend: Figure 1A: front view of reflective markers.
Figure 1B: sagittal view of reflective markers affixation
Figure 1. Affixation of reflective markers on anatomical points

The gait protocol consisted of performing steps on the platform, and in all attempts, the subject made the same route of the familiarization session. Attempts were made until eight steps were fully captured, following the Laroche protocol[18]. The laboratory technician was responsible for positioning the markers for evaluation, as well as for recording the angular and linear gait variables.

As for the healthy and affected limbs, the study evaluated the variables gait speed, maximum angles of flexion and extension of the hip and knee. Ankle angulations were disregarded due to the use of orthoses by the participants. It used the values described by Neuman[19] as a reference for normality of the data. The data collected were analyzed using the statistical program SPSS 21.0 (Statistical Package for the Social Sciences for Windows). The study used descriptive statistics with simple and relative frequency distribution, as well as measures of central tendency (mean/median) and variability (standard deviation and interquartile range) to describe the variables. In the analysis to compare the members, it applied the *t*-paired test for dependent data and, for comparisons with normality, the *t* test for average of a sample. As a decision criterion, the significance level adopted was equal to or less than 5% ($p \leq 0.05$)[20].

RESULTS

The study included 17 patients, eight men and nine women, of whom 12 were hemiplegic on the left and five on the right. Table 1 shows the anthropometric characteristics of the injury and functionality of the sample, in which considerable variability in length time of injury is observed (7.5 to 23.5 months) and at the level of functionality (58 to 126 points).

Table 1. General characteristics of the participants

Sample characterization	Md (SD)	Med (25-75)	Min.	Max.
Age (years)	48.35 (8.63)	50 (43.50-55.50)	31	59
Weight (kg)	70.27 (12.49)	70 (61.5-77.5)	49.9	93
Height (meters)	1.63 (0.10)	1.61 (1.56-1.74)	1.50	1.81
CVA time (months)	30 (46.85)	12 (7.50-23.50)	7.5	23.5
FIM	110 (22.00)	122 (105-125)	58	126

Legend: Md – mean; Med – median; SD – standard deviation; Min. – minimum; Max. –maximum; CVA – stroke-cerebrovascular accident; and FIM – Functional Independence Measurement Scale. Functional Independence Measure.

Considering the gait, it showed a mean velocity of 0.44 meters/second (± 0.32), significantly below the 1.37 meters/second, considered normal by Neumann et al.[19]

In the analysis of the angular variables, results showed differences in the angulations between affected and healthy limbs, highlighting a significant difference for flexion (0.001) and knee extension (0.05), with no remarkable variability between limbs in hip angulations. Also, in the affected limb, the median indicates variability in the patients' pattern, although the hip and knee flexor pattern prevailed (Table 2).

Table 2. Mean of the angular variables comparing the affected limb with the healthy one

AKV	Healthy		Affected		p (0.05*)
	Mean ± SD	Median (25-75)	Mean ± SD	Median (25-75)	
Hip flexion	32.99 ± 12.39	36.50 (23.12-42.07)	33.23 ± 14.85	30.30 (23.78-37.80)	0.17
Hip extension	-3.18 ± 10.75	-1.95 (-12.75-4.74)	0.58 ± 12.87	3.37 (-11.58-10.75)	0.13
Knee flexion	58.94 ± 7.94	60 (55.55-64.43)	35.73 ± 15.84	34.27 (25.82-49.95)	0.001*
Knee extension	8.34 ± 6.97	7.51 (5.15-12.72)	3.20 ± 12.34	3.84 (-8.93-14.18)	0.05*

Legend: AKV – angular kinematic variables, SD – standard deviation.

The averages of angular variables compared with normality are described in Table 3. In the comparison between affected limb and normality, there is a significant difference in knee flexion angles (< 0.000) and hip extension (0.004), indicating a lower angular variation of these joints during gait.

Table 3. Mean of the angular variables comparing the affected limb with the normality

AKV	Affected Member		Normality**	p (0.05*)
	Mean ± SD	Median (25-75)		
Hip flexion	33.23 ± 14.85	30.30 (23.78-37.80)	30º	0.382
Hip Extension	0.58 ± 12.87	3.37 (-11.58-10.75)	-10º	0.004*
Knee flexion	35.73 ± 15.84	34.27 (25.82-49.95)	60º	<0,000*
Knee Extension	3.20 ± 12.34	3.84 (-8.93-14.18)	0º	0.30

Legend: AKV – angular kinematic variables, SD – standard deviation, * – significant, ** = Neumann[19].

DISCUSSION

The main objective of the present study was to evaluate the changes in the angular kinematics of the gait of post-CVA hemiparetic patients, comparing the affected side with the healthy side and the normality. The results demonstrated significant changes in angular kinematics of gait in hemiparetic patients, both in comparison between limbs and in the relationship with normality, prevailing the pattern of hip and knee flexion during locomotion. In addition, the gait speed of the evaluated participants was below the values suggested by the literature[19].

Concerning the characteristics of the participants, the length time of injury can also interfere with the patient’s functionality since individuals with longer time of injury, or who are no longer in the acute phase, present an already established gait pattern[21]. As for the level of functionality, the participants presented considerable variability in the evaluation of FIM. Lee et al.[13] indicate that the degree of impairment and the patient’s function interfere with the changes observed in gait, and mild patients tend not to present significant alterations. Silva and Jacinto[22] reinforce that functional measures are directly related to the changes observed in the locomotion pattern of patients.

Regarding speed, the study observed that the individuals had values lower than the normality[19], indicating that hemiparesis tends to generate a slower gait pattern, as demonstrated in previous studies[8,9,15]. This result is directly related to the decrease in the joint ranges of motion of these individuals since the lower their mobility, the shorter their step and stride length, generating a gait pattern with a reduced speed[10,13]. Still, the greater the spasticity, the greater the velocity deficit[9] since spasticity is directly related to a decrease in muscle activation capacity and force production; it generates muscle weakness, especially in hip flexors, knee extensors, and ankle dorsiflexors, which are determinants for maintaining gait speed[10]. Silva and Jacinto[22], in their study with 34 hemiparetic patients, also highlighted the relationship between gait speed and angular variables. The authors indicated that the closer to normal the hip angle, the better the gait speed of the individual[22]. Boudarham et al.[10], when evaluating 42 hemiparetic patients, reinforce that the presence of angular alterations in the hip and knee are related to decreased speed.

Considering the analysis of angular kinematics, in the comparison between healthy limb and affected limb, the latter showed a lower range of motion in the examination of hip flexion and extension, but without statistical difference. On the other hand, the extension amplitude and flexion of the knee of the affected limb were significantly lower than those of the healthy limb. Westphalia et al.[8] evaluated eight post-CVA individuals and found decreases in hip and knee angulations of the affected limb, but only knee flexion showed a significant difference. Neckel et al.[12] also found asymmetry between the limbs of post-CVA patients, with mean values of hip extension and knee flexion significantly different in the evaluation of ten patients, demonstrating abnormal asymmetrical patterns in the hip and knee.

As for the comparisons with the normative parameters, hip extension, and knee flexion were significantly lower than the reference values. The flexor pattern of the knee joint has also been highlighted in previous studies that have demonstrated a gait with a predominance of knee flexion and little extension of this joint post-CVA, also showing lower mean values for knee ranges of motion[8,13,23]. Silva and Jacinto[22] stated that changes in the knee, since this joint has the widest range of motion in the sagittal plane, have an impact on the progression of the front limb caused by spasticity and lack of strength in these patients. This lower knee flexion range of motion leads to compensatory strategies in the hip joint that are characteristic of hemiparetic gait[23]. Although the knee flexor pattern prevailed in the evaluated patients, with less angular variation than normal, Fernández et al.[24] cite that some patients may present hyperextension in the support phase, which was also observed in some patients in this study. The hip angle values, when compared with those of normality, also reinforce the pattern generally observed in post-CVA patients; they describe reduced peak hip joint extension, changes in pelvic positioning and knee flexion, as well as decreased ankle movement[25]. Westphalia et al.[8] and Fernández et al.[24] also highlight the decrease in hip extension in hemiparetic patients.

Overall, changes in the ranges of motion of ankle dorsiflexion, hip flexion, and knee are responsible for this pathological gait pattern[10]. When comparing CVA patients and healthy individuals, Lee et al.[13] indicate differences in the ability to generate joint movement, with a decrease in the angulations of the hip and knee joints. These changes may be mainly related to decreased balance and motor control, muscle weakness, proprioceptive deficit, increased tone, contractures, and deformities caused by the disuse of the muscles on the affected side[15]. Stanhope et al.[23] also highlight the relationship between hip and knee, indicating that compensatory hip strategies are observed in hemiparetic gait in response to reduced knee and ankle movement.

CONCLUSION

Patients with hemiparesis present changes in the angular kinematics of gait when the affected limb is compared with the healthy and normal, demonstrating a predominantly flexor gait pattern. Although the present study has a small sample size and did not include a control group, the results may contribute to the therapeutic approach to patients with hemiparesis. Understanding the angular changes in gait makes it possible to establish strategies to correct the patient's pathological pattern, enhancing the results of the rehabilitation process.

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