Saúde e Pesquisa
DOI: 10.17765/2176-9206.2022v15n2.e10447

Changes in the kinematics of hemiparetic gait: a comparative study

Alterações na cinemática da marcha hemiparética: um estudo comparativo

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ABSTRACT
The main objective of this study was to analyze the gait alterations of adults with hemiparesis after cerebrovascular accident (CVA) and compare it with healthy subjects. The sample consisted of 14 participants from the stroke group and 14 matched participants from the control group (CON). A three-dimensional gait analysis was performed using a kinemetry system. The parameters analyzed were velocity, stride length, stride width, cadence, and stride time, using the independent t test for comparisons between groups and considering $p < 0.05$ as a decision criterion. Participants in the stroke group had significantly lower mean values in all analyzed parameters. In addition, patients in the CVA group also had much lower values when compared to other studies with post-CVA patients, possibly due to the short period between the CVA (mean of 14.14 months) and the gait assessment.

Keywords: Brain stroke. Gait. Hemiparesis.

RESUMO
O objetivo principal deste estudo foi analisar as alterações da marcha de adultos com hemiparesia após acidente vascular encefálico (AVE) e comparar com sujeitos saudáveis. A amostra foi composta por 14 participantes do grupo AVE e 14 participantes pareados do grupo-controle (CON). Foi realizada uma análise tridimensional da marcha mediante um sistema de cinemetria. Os parâmetros analisados foram a velocidade, o comprimento da passada, a largura da passada, a cadência e o tempo da passada, sendo utilizado o teste *t* independente para as comparações entre os grupos e considerando $p < 0,05$ como critério de decisão. Os participantes do grupo AVE apresentaram valores médios significantemente inferiores em todos os parâmetros analisados. Além disso, os pacientes do grupo AVE também tiveram valores muito inferiores quando comparados aos de outros estudos com pacientes pós-AVE, possivelmente devido ao curto período entre o AVE (média de 14,14 meses) e a avaliação da marcha.

Palavras-chave: Acidente vascular encefálico. Hemiparesia. Marcha.

Received in November 04, 2021
Accepted on February 05, 2022

INTRODUCTION

Stroke (CVA) affects approximately 16 million people and causes 6 million deaths per year worldwide[1]. In Brazil, it is estimated that 568,000 people have severe disabilities resulting from this pathology[1]. Stroke is one of the main causes of mortality and physical and cognitive disabilities in the world[2]. Although mortality rates are decreasing, population aging has increased the number of people with difficulties in carrying out their activities of daily living (ADL) as a result of a CVA.[3-4].

Spastic hemiparesis is seen as the most common impairment after a stroke, being related to muscle deficits and decreased sensory function, so it is considered the main responsible for the physical disabilities of this population[5-7]. Impaired locomotion is one of the most reported functional alterations[8-9]. It is estimated that two out of three people experience persistent difficulties in performing an adequate gait after a CVA[10]. Previous studies have shown that changes in balance resulting from spastic hemiparesis are considered the main causes of changes in gait pattern, which can lead to instabilities during post-stroke locomotion[11-13]. Instability during gait is the main factor for the increased risk of falls after a stroke [14-15], despite the understanding that falls have a multifactorial origin[16-17]. According to Belgan et al.[18], up to 70% of people who have suffered a CVA have at least one fall episode per year.

In this context, the biomechanical analysis of the gait of hemiparetic individuals is a very important assessment method, as the gait analysis can be used to assess the risk of falls[19]. Among the assessment tools, three-dimensional analysis is a valid approach to assess various motor disorders, offering excellent reproducibility and reliability in post-stroke hemiparetic patients[20-21].

So, understanding that stroke has a high incidence in the Brazilian population and that gait is one of the most important functional losses, studies in this area are relevant. The identification of possible changes in the biomechanical parameters of gait can help in therapeutic planning, aiming to improve the gait pattern and the consequent decrease in the risk of falls in this population.

Therefore, the main objective of this research was to analyze the changes in the gait kinematics of adults with hemiparesis after CVA compared to healthy subjects.

METODOLOGY

This study was characterized as descriptive and observational, with a comparative character and cross-sectional approach. It is part of a project approved (protocol 2,230,696) by the Ethics and Research Committee of the Federal University of Health Sciences of Porto

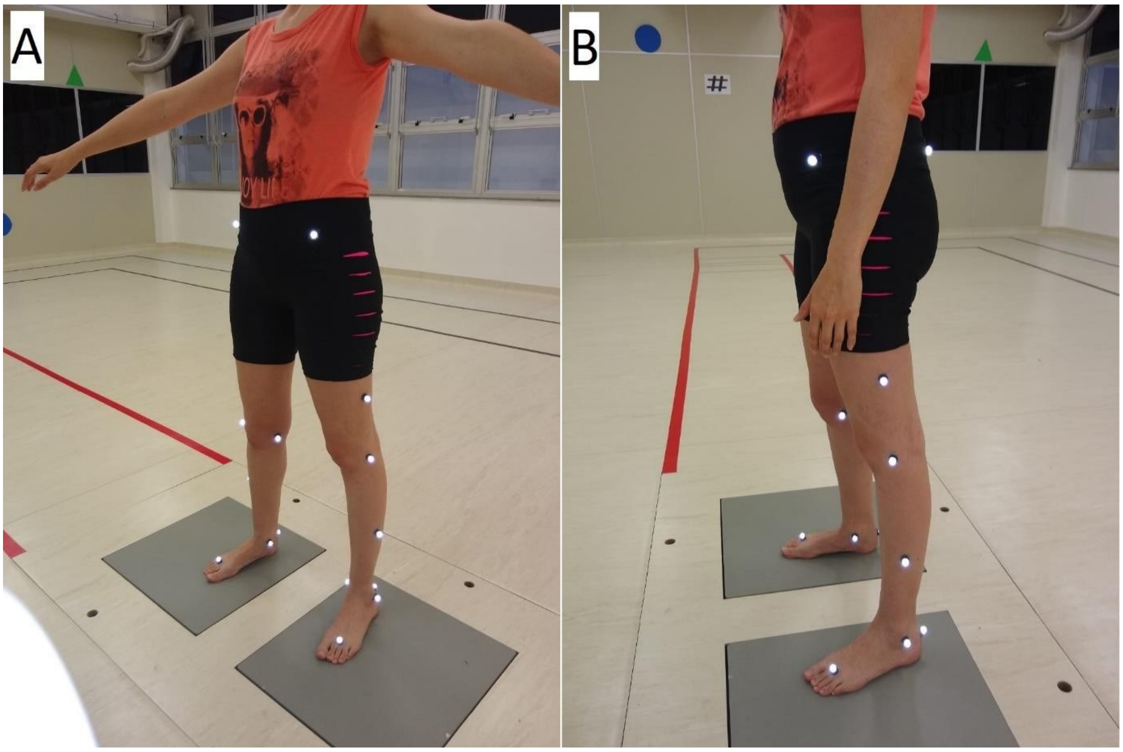
Alegre (Porto Alegre, Rio Grande do Sul, Brazil) and carried out in accordance with the legal provisions of Resolution No. 510, of April 2016, of the National Health Council, which approves the guidelines and regulatory standards for research involving human beings. The place where this study was carried out was the Laboratory of Biomechanical Analysis of Human Movement, at the Clinical Center of the University of Caxias do Sul (CECLIN-UCS).

Twenty-eight adults participated, divided into two groups: Stroke Group, composed of 14 patients who had suffered a stroke and had spastic hemiparesis; CON group, composed of 14 healthy adults, constituting the control group. The study took place between September 2020 and August 2021, and the sample was intentional and non-probabilistic, age matched. Inclusion criteria were: adult age group, between 40 and 59 years; clinical diagnosis of stroke with spastic hemiparesis; registration with CECLIN-UCS; walking ability with or without a device; signing of the Free and Informed Consent Form (ICF). Individuals who presented: cognitive impairment or visual impairment were excluded from the research; flaccid hemiparesis; cardiovascular diseases; difficulties that made it impossible to pass the test.

To carry out the study, firstly, a search was carried out in the CECLIN-UCS patient register and analysis of medical records for the selection of post-stroke patients with spastic hemiparesis, according to the inclusion criteria. Then, the CON group was determined, considering age matching and a maximum interval of one year of difference between the participants of the CVA and CON Group. Then, telephone contact was made with the patients, explaining to them about the study and inviting them to participate. On the previously scheduled date, individuals filled out a questionnaire with personal identification, anthropometric and health information. Subsequently, they signed the informed consent and were directed to the gait assessment test.

The procedures for collecting gait data were based on the protocol by Laroche et al.[22]. To adapt the participants to the evaluation protocol, the subjects were first asked to walk 8 meters in a straight line at self-selected velocity, in the place destined for the gait collection in the laboratory. Afterwards, reflective markers were affixed to the following anatomical points (right and left): anterosuperior iliac spines, posterosuperior iliac spines, medial-lateral portions of the femurs, medial-lateral portions of the knees, medial-lateral portions of the tibias, lateral malleolus of the ankles, center-posterior portions of the calcaneus and dorsal surface of the second metatarsals, as seen in Figure 1. Several attempts were made until eight steps were fully captured.

To capture the three-dimensional trajectory of the markers positioned on the subjects' bodies during gait, a kinemetry system equipped with seven integrated cameras (VICON MX systems, Oxford Metrics Group, United Kingdom) was used. Kinematic data were collected at a sampling rate of 100 Hz.



Caption: A) posting of reflective markers (front view); B) affixation of reflective markers (sagittal view).

Figure 1. Affixing reflective markers to anatomical points

The following linear kinematics variables were considered: a) spatio-temporal variable: gait velocity; b) spatial variables of gait: stride length, stride width; c) temporal variables of gait: stride time, cadence. The collected data were analyzed using the SPSS 17.0 statistical program (Statistical Package for the Social Sciences). To describe the kinematic variables of gait, descriptive statistics were used with simple and relative frequency distribution, as well as measures of central tendency (mean/median) and variability (standard deviation). For comparisons, the independent t test was used, considering $p < 0.05$ as the decision criterion[23].

RESULT

The general characteristics of the participants are presented in Table 1. The data demonstrate homogeneity between the groups. Regarding age, both groups had a mean age of 51 years, ranging between 43 and 59 years in the CVA group and between 41 and 59 years in the CON group.

Table 1. General characteristics of participants

Sample characterization	CVA group	CON group	t	p
	Mean (±SD)			
Age (years)	51.29 (±5.56)	51.21 (±6.10)	0.03	0.97
Body mass (kg)	72.33 (±13.33)	76.97 (±13.70)	-0.90	0.37
Stature (m)	1.62 (±0.09)	1.68 (±0.08)	-1.76	0.09
Injury time (months)	14.14 (±15.40)	-		-

Caption: CVA group – group composed of post-stroke patients with spastic hemiparesis; CON group – control group composed of healthy adults; SD – standard deviation; kg – kilograms; m - meters.

In Table 2, the kinematic variables of gait are described, demonstrating a significant difference between the groups, in which hemiparetic patients present lower results in all parameters evaluated.

Table 2. Mean of kinematic variables comparing the two groups

Kinematic variables	CVA group	CON group	t	p
	Mean ± SD			
Space-time				
Velocity (m/s)	0.39 (±0.24)	1.24 (±0.10)	-12.12	< 0.0001
Spatial				
Stride length (m)	0.64 (±0.24)	1.29 (±0.10)	-9.14	< 0.0001
Stride width (m)	0.22 (±0.05)	0.18 (±0.03)	2.36	0.02
Storms				
Cadence (steps/s)	67.15 (±25.85)	115.42 (±5.43)	-6.83	< 0.0001
Past time (s)	3.60 (±2.49)	1.04 (±0.04)	3.82	0.001

Caption: Stroke group – group composed of post-stroke patients with spastic hemiparesis; CON group – control group composed of healthy adults; SD – standard deviation; kg – kilograms; m – meters; steps/s – steps per second; s – seconds; m/s – meters/second.

DISCUSSION

The results of the present study showed that participants in the stroke group with spastic hemiparesis exhibited lower performance than those in the control group in all gait kinematic parameters analyzed (velocity, stride length, stride width, cadence, stride time). Due to the functional importance, gait recovery should be among the main goals of rehabilitation[24]; however, individuals who suffer a CVA do not always receive adequate and necessary attention for the functional recovery of gait[25-26]. The analysis of spatio-temporal, spatial and temporal variables allows researchers and professionals who work with rehabilitation to understand the abnormal pattern of post-stroke gait[27].

Unlike most gait studies with this population, in this study the kinematic parameters were collected by a three-dimensional technology system, currently considered the gold standard for gait assessment and treatment planning in various patient populations[28]. Another important point to be highlighted is in relation to the age of the participants: all adults aged between 41 and 59 years old (average of 51.29 years old). This mean age can be considered low, as it is known that most cerebrovascular events affect the elderly. Because of this, most studies that evaluated the gait of patients after a CVA did so in elderly people with a mean age of 60.8 years[29], 62.5 years30, 62.7 years[20], 64.1 and 69.0 years[19] and 64.7 years[31].

As for gait velocity, the results of this study showed that the mean value of the CVA group was significantly lower when compared to the healthy group. Velocity during locomotion is the most studied kinematic parameter due to its functional importance, being considered a predictor of independence[32-33]. Clinically, slower gait velocity is directly related to a decrease in exercise capacity, muscle activation and force production[34]. Gait velocitys between 0.40 and 0.80 m/s are considered low velocitys, characterizing limited locomotion[35]. Boudarham et al.[36], Curuk et al.[37] and Geiger et al.[21] evaluated the gait of post-stroke adults with mean ages of 52, 54.4 and 58.2 years, respectively, and showed low velocitys. However, the average velocity of the stroke group in the present study was 0.39 m/s, much lower than the 0.78 m/s36, 0.76 m/s[37] and 0.77 m/s[21] of the previously mentioned studies. Based on these results, it can be considered that the participants of this research had lower functional levels when compared to other studies with adults after stroke[11]. In addition to indicating a decrease in functionality, decreased gait velocity in hemiparetic patients has the main objective of maintaining postural stability and reducing the risk of falls[31,38], as hemiparetic gait is asymmetrical and compromises body balance[39]. Still, considering sensorimotor aspects, muscle weakness of the hip flexors, knee extensors and ankle dorsiflexors are determining factors and justify the observed decrease in velocity[40]. This hemibody weakness, associated with spasticity, lack of selective motor control, and poor proprioception, limits the subject's ability to increase velocity during locomotion[40-41].

In addition to the significant decrease in the spatio-temporal parameter (velocity) of gait, stride length and cadence also showed significantly lower values;

while the width and time of the stride showed higher values in comparison with the healthy group. In the analysis of spatial parameters, while Boudarham et al.[36] and Geiger et al.[21] demonstrate values close to 1.00 meter for stride length and around 0.20 meter for stride width, the average values of the participants in this study were 0.64 and 0.22 meters, respectively. In the analysis of temporal variables (cadence and stride time), the CVA group had an average value of 67.15 steps per minute for cadence, while the average values of other studies with post-CVA adults were 91.0036, 94, 4421 and 96.0637 steps per minute. In the stride time, the mean value was 3.60 seconds, while post-stroke adults in the work by Boudarham et al.[36] had mean values of 1.35 seconds, almost 50% lower than those in the present study. These changes observed in patients are necessary adaptations to support gait function, given the numerous sensorimotor changes that occur after a stroke. The patient uses the shortest step, probably to reduce the time of support on the affected limb, staying longer in double support. This, added to the increase in base and slower displacement, reduces gait instability, providing greater patient safety[40].

It should be noted that the quantification of these variables provides more information about the health status of the subjects evaluated[27], even serving to assess the risk of mortality[42]. These changes in spatial and temporal variables indicate adaptations in the locomotor system to perform safer and more efficient locomotion[29]. The results found are typical of patients who have suffered a stroke and have spastic hemiparesis, as demonstrated in the systematic review by Sheffler and Chae[11]. However, despite being expected results for this population, participants in the CVA group showed much lower performance when compared with data evidenced by other studies that evaluated post-CVA adults[21,36-37]. The justification for these results may be related to the average period of 14.14 months between the stroke episode and the evaluation. In other studies that evaluated the gait of adults after a stroke, the mean time between the stroke and the assessment was 59 months[36], 79.9 months[37] and 116.4 months[21], much higher than the 14.14 months in the present study. The great variability in the locomotion of post-stroke patients is dependent on the severity of the sensorimotor system, the time of injury and time of rehabilitation. Studies indicate that the longer the rehabilitation time, the greater the chances of improving the gait pattern, and the variations are closely related to the degree of recovery[43-44]. So, the results of this study demonstrated the great influence of the factor "recovery time after the stroke" in the functional recovery of these subjects.

CONCLUSION

Therefore, based on the results of the present study, it can be concluded that adult individuals who have suffered a stroke and who present spastic hemiparesis have significant alterations in the spatio-temporal parameters of gait when compared to healthy subjects. The performance of individuals in this study was also much lower, in the five parameters evaluated, when compared to post-stroke adults in other studies. These results, which possibly occurred due to the short period between the stroke and the evaluation, suggest low levels of functional performance and an increase in the risk of falls.

The use of precise biomechanical methods to quantify changes in the gait of post-stroke hemiparetic individuals will have implications for the quality of life of these patients, as it enables preventive, care and rehabilitation actions aimed at their real needs. Individualized therapeutic approaches tend to be more effective, enhancing functional results and, consequently, reducing the risk of falls in these individuals.

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