Annals of Clinical and Analytical Medicine
Original Research

Investigation of the spatio-temporal gait parameters in individuals with hemiparesis: The effect of lateralization

Gait parameters in hemiparetics

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This study was presented as a poster presentation in European Congress of Neurorehabilitation 2019 (ECNR), 9-12 October Pudapest, Hungary.

Abstract
Aim: The aim of this study was to investigate the effect of lateralization on the spatio-temporal characteristics of gait in individuals with hemiparesis.
Material and Methods: A total of 108 individuals aged 20-65 years were included in the study. Thirty-six individuals were right hemiparetics (Group 1: 16F, 20M), 36 were left hemiparetics (Group 2: 16F, 20M) and 36 were healthy controls (Group 3: 19F, 17M). The Gait Analysis System was used to assess the spatio-temporal gait characteristics.
Results: The demographic and clinical characteristics of the groups were similar (p>0.05). When gait analysis, results were compared according to lateralization, the gait of the individuals in Group 1 was more symmetrical (p<0.05) and pelvis movements were more asymmetric than in Group 2 (p>0.05). When gait parameters of hemiparetic individuals were compared to healthy individuals, the cadence, gait speed, stride length and gait symmetry of the hemiparetic individuals were lower, but the gait period was longer than in Group 3 (p<0.05). Pelvic tilt, pelvic obliquity, and pelvic rotation symmetries of the hemiparetic individuals were lower than in Group 3 (p<0.05).
Discussion: Lateralization affects the spatio-temporal characteristics of gait in individuals with hemiparesis. Right hemiparetic individuals have a more symmetrical gait and asymmetric pelvis movements when compared to the left hemiparetic individuals.

Keywords
Gait; Hemiparesis; Lateralization; Spatio-Temporal Analysis

DOI: 10.4328/ACAM.20643 Received: 2021-04-06 Accepted: 2021-06-22 Published Online: 2021-07-15
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Introduction

Hemiparesis is a clinical table in which one- half of the body performs its processes with mental, visual, intellectual and emotional disorders as well as motor and sensory loss [1]. These deficiencies, observed in hemiparetic patients, cause localization of the affected zone, and also the functional losses in different levels depending on the severity of affection. These functional losses are the disorder of balance and coordination, asymetric stance, increase in muscle tonus, postural control disorder, sensory and proprioceptive losses, cognitive problems and gait disorders [2].

Basic locomotor patterns that may distort the selective motor control occur in the period after stroke. This situation leads to changes in the intensity and severity of the normal timing in paretic extremity and muscle spasms [3]. This situation causes changes during gait in the parameters of speed, cadence, step length, stride length, length width, stance and swing phases and the time intervals of single support and double support periods [3,4].

Functional results of stroke change depending on the hemisphere involvement. The reason for this stems from the fact that right and left hemispheres control the tasks differently from each other [5]. For this reason, this study was conducted to investigate the spatio-temporal gait characteristics in right and left hemiparetic individuals and compare their differences with the gait of the healthy individuals.

Material and Methods

The present study was conducted at Pamukkale University, School of Physical Therapy and Rehabilitation, Department of Neurological Rehabilitation between June 2017-May 2018. This study was approved by Pamukkale University Medical Ethics Committee of Non-Interventional Clinical Researches (Approval date: 04.07.2017, no:09).

Participants:

As a result of the power analysis, it was calculated that when 108 people were taken into the study (36 for each group), 95% power with 80% confidence would be obtained. A total of 108 volunteer individuals aged between 20-65 years participated in the study. Thirty-three participants were right hemiparetic (Group1: 16 females, 20 males), 36 participants were left hemiparetic (Group2: 16 females, 20 males), and 36 participants were healthy controls (Group 3: 19 females, 17 males).

Inclusion Criteria: Hemiparetic individuals aged 20-65 years, who had a stroke for the first time and one-sidedly, whose clinical state was stable, who had no cognitive disorder (Hodkinson Mental Test≥ 8), who received ≤ 3 points on the Modified Rankin Scale and those without vision and hearing problems were included in the study. Inclusion criteria for a healthy control group were to be between the ages of 20-65 and have no neurological, musculoskeletal, cardiac and cognitive problems that they had previously experienced and that could affect walking.

Exclusion Criteria: Individuals who had any orthopedic, neurological or psychiatric problems that may affect walking and vision and hearing problems in both study and control groups were excluded.

All participants were informed about the study and their verbal and written consent was obtained before the study. After taking approvals, demographic and clinical data were recorded. Spatio-temporal characteristics and pelvis kinematics of gait were assessed with BTS G-Walk® Gait Analysis System.

Assessment Methods:

1. Hodkinson Mental Test: It is used to assess cognitive functions. It consists of 10 questions in total. In the test whose minimum score is 0 and maximum score is 10, a score between 6-8 indicates slight cognitive disorder, a score between 4-6 indicates cognitive disorder in medium level and a score lower than this indicates heavy cognitive disorder [6].

2. Modified Rankin Scale: It is used to assess recovery after stroke. The scale, reliability and validity of which were conducted by Swieten et.al. in 1988 is graded between 0-6 points. On the scale whose score increases as the disability ratio increases; those with 1 and 2 points sustain their daily lives independently, and those with 3 and higher points sustain their daily lives dependently [7,8].

3. Assessment of the Gait Parameters: The BTS G-Walk Spatio-Temporal Gait Analysis System used for this test is the system in which the spatio-temporal characteristics, gait symmetry indexes of the individuals and the kinematic investigations in the pelvis and spine are provided with the help of a transport transmitted via Bluetooth. It is fastened to L5-S1 level with a pelvic belt and the activity of the individual convenient for the determined clinical test is demanded. The data of the patient is transmitted to a computer with the help of the connected transport and automatic reports are formed. It is used for soft tissue injuries, amputation and secondary walking problems associated with neurological illnesses [9] (available at: https://www.imeko.org/publications/tc4-2014/IMEKO-TC4-2014-333.pdf). In this study, gait parameters have been recorded with the use of the BTS G-Walk Wireless Digital Gait Analysis System on a 10-meter smooth walking area.

Statistical Analysis: The analysis of the data attained from the study was conducted with SPSS for Windows 22.0 statistical package program. The significance level was obtained as $p<0.05$. Descriptive statistical data were given as mean ± standard deviation (X±SD) or percentage (%). All measurements were checked for normality with the Kolmogorov-Smirnov test. When parametric test assumptions were provided, Student's t-test was used in the comparison of the independent group differences; when the parametric test assumptions were not met, the Mann-Whitney U test was used in the comparison of the independent group differences [10].

Results

The mean age of the participants was 51.25±12.81 years for Group 1, 50.42±11.28 years for Group 2, and 50.11±11.99 years for Group 3. The Mean period of hemiparesis was 19.74±28.08 months for Group 1 and 25.61±36.19 months for Group 2. The groups were similar in terms of age and hemiparesis periods ($p>0.05$). The demographic and clinical characteristics of the groups are given in Table 1.

When the spatio-temporal parameters were compared, both in Group 1 and in Group 2, swing phase were longer than stance phase of the hemiparetic side, and also single support period for the hemiparetic side was lower. When Group 1 and 2 were compared in terms of the gait symmetry percentage, it was found that the gait of Group 1 is more symmetrical (p=0.026) (Table 2).

When the gait parameters of Group 1 and 3 were compared, it was seen that the cadence, gait speed, stride length, ratio of the step length to the height, and gait symmetry of Group 1 were lower, time of gait period was longer for Group 1(p<0.05) (Table 2).

When the gait parameters of Group 2 and 3 were compared, the cadence, gait speed, stride length, ratio of the step length to the height, right swing phase, left single support period and gait symmetry of Group 2 were lower, time of walking period and right stance phase period were longer for Group 2 (p<0.05) (Table 2).

When comparing pelvis kinematics in Group 1 and 2, pelvic tilt, pelvic obliquity and pelvic rotation movements of Group 1

Table 1. Demographic and Clinical Characteristics of Individuals

Variables	Group 1 X±SD	Group 2 X±SD	Group 3 X±SD	p1,2	p1,3	p2,3
Age (year)	51.25±12.81	50.42±11.28	50.11±11.99	0.771	0.698	0.912
BMI (kg/m^2)	26.09±4.26	27.92±4.49	29.13±5.97	0.080	0.015*	0.336
Hemiparesis time (month)	19.74±28.08	25.61±36.19		0.960		
	n (%)	n (%)	n (%)			
Gender						
F	16(44)	16(44)	19(53)			
M	20(56)	20(56)	17(47)			
Dominant Side						
	33(92)	33(92)	36(100)			
	3(8)	3(8)	0(0)			
Causes			dddd			
Ischemia	20(56)	14(39)				
Hemorrhage	8(22)	7(19)				
Tumor	3(8)	7(19)				
Trauma	2(6)	2(6)				
Aneurysm	3(8)	6(17)				
Aid Device						
No	29(80)	27(75)				
Tripod	6(17)	5(14)				
Canadian	1(3)	4(11)				

Group 1: Right hemiparesis individuals, Group 2: Left hemiparesis individuals, Group 3: Healthy individuals, BMI: Body mass index, n: Number of people, X: Mean, SD: Standard deviation, kg/m^2:kilogram/square meter, Canadian: Forearm supported walking cane, F: Female, M: Male, R: Right, L: Left, p1,2: The significance level of groups 1 and 2, p1,3: The significance level of groups 1 and 3, p2,3: The significance level of groups 2 and 3, *: Independent samples t- test.

Table 2. Comparison of the Gait Parameters Results of Groups

Gait Parameters	Group 1 X±SD	Group 2 X±SD	Group 3 X±SD	p1,2	p1,3	p2,3
Cadence (step/min.)	88.87±18.24	82.82±17.40	108.88±12.71	0.155*	0.000*	0.000*
Gait Speed (m./sec.)	0.70±0.38	0.66±0.32	1.124±0.26	0.723[t]	0.000t[t]	0.000[t]
Left Stride Lenght (m.)	0.94±0.35	1.03±0.48	1.24±0.20	0.351*	0.000*	0.020*
Right Stride Lenght (m.)	0.94±0.35	1.03±0.49	1.24±0.21	0.352*	0.000*	0.024*
Ratio of Left Step Lenght to Heigh (%)	56.22±19.90	60.89±27.65	75.95±11.89	0.414*	0.000*	0.004*
Ratio of Right Step Lenght to Height (%)	56.31±19.98	60.98±27.82	75.73±12.02	0.416*	0.000*	0.005*
Left Step Length (%)	47.71±5.62	50.13±5.95	48.99±1.90	0.115[t]	0.464[t]	0.260[t]
Right Step Length (%)	52.30±5.62	49.87±5.95	51.01±1.90	0.115[t]	0.464[t]	0.260[t]
Left Stance Phase (%)	62.41±6.09	57.31±10.29	60.98±2.28	0.035[t]	0.066[t]	0.171[t]
Right Stance Phase (%)	58.09±5.96	63.57±7.18	60.11±2.06	0.001[t]	0.084[t]	0.001[t]
Left Swing Phase (%)	37.59±6.09	42.63±10.29	39.02±2.28	0.035[t]	0.066[t]	0.171[t]
Right Swing Phase (%)	41.91±5.96	36.43±7.18	39.89±2.06	0.001[t]	0.084[t]	0.001[t]
Left Double Support Period (%)	10.60±2.58	9.82±3.56	10.43±2.29	0.288*	0.757*	0.392*
Right Double Support Period (%)	9.99±3.13	10.89±4.43	10.53±2.08	0.321*	0.396*	0.653*
Left Single Support Period (%)	41.76±6.03	36.57±7.01	40.06±2.00	0.001[t]	0.241[t]	0.001[t]
Right Single Support Period (%)	37.64±6.03	42.80±10.38	39.01±2.25	0.034[t]	0.062[t]	0.180[t]
Walking Symmetry (%)	83.21±13.92	74.72±17.38	96.53±2.39	0.026[t]	0.000[t]	0.000[t]

Group 1: Right hemiparesis individuals, Group 2: Left hemiparesis individuals, Grup 3: Healthy individuals, p1,2: The significance level of groups 1 and 2, p1,3: The significance level of groups 1 and 3, p2,3: The significance level of groups 2 and 3, X: mean, SS: Standard deviation, *: Independent samples t test, t: Mann-Whitney U test.

Table 3. Comparison of Pelvis Movement Results of Groups

Pelvic Parameters	Group 1 X±SD	Group 2 X±SD	Group 3 X±SD	p1,2	p1,3	p2,3
Pelvic Tilt Symmetry (%)	39.46±31.68	41,.15±25.86	59.02±23.05	0.805*	0.004*	0.003*
Left Pelvic Tilt Angle (⁰)	6.16±3.57	6.42±4.00	4.81±2.06	0.978^t	0.101^t	0.112^t
Right Pelvic Tilt Angle (⁰)	6.10±3.51	6.28±3.81	4.80±2.12	0.973^t	0.112^t	0.146^t
Pelvic Oblique Symmetry (%)	69.78±30.76	77.39±22.80	97.94±1.38	0.581^t	0.000^t	0.000^t
Left Pelvic Oblique Angle (⁰)	4.89±2.80	5.64±2.71	7.67±1.86	0.252*	0.000*	0.000*
Right Pelvic Oblique Angle (⁰)	4.90±2.69	5.44±2.60	7.72±1.93	0.393*	0.000*	0.000*
Pelvic Rotation Symmetry (%)	77.49±22.67	83.63±14.59	96.21±5.06	0.539^t	0.000^t	0.000^t
Left Pelvic Rotation Angle (⁰)	8.32±4.75	9.95±4.99	10.38±3.60	0.159*	0.042*	0.680
Right Pelvic Rotation Angle (⁰)	8.76±5.19	9.72±4.68	10.94±3.99	0.415*	0.050*	0.237

Group 1: Right hemiparesis individuals, Group 2: Left hemiparesis individuals, Grup 3: Healthy individuals, p1,2: The significance level of groups 1 and 2, p1,3: The significance level of groups 1 and 3, p2,3: The significance level of groups 2 and 3, X: mean, SD: Standard deviation, *: Independent samples t- test, t: Mann-Whitney U test.

Figure 1. Flow chart of the study

were more assymetric, but there was no statistical significance between the groups in terms of pelvic movements (p>0.05). When comparing pelvic movements in Group 1 and 3, pelvic tilt symmetry, pelvic obliquity symmetry, pelvic rotation symmetry, right and left pelvic obliquity angle and pelvic rotation angle in Group 1 were lower (p<0.05). When the pelvic movements in Group 2 and 3 were investigated, it was seen that pelvic tilt, pelvic obliquity and pelvic rotation symmetry, right and left pelvic obliquity angle in Group 2 were lower than in Group 3 (p<0.05) (Table 3).

Discussion

In this study, which investigated the impact of lateralization on spatio-temporal gait characteristics in hemiparetic individuals, it was detected that the gait parameters are affected by lateralization in hemiparetic individuals. It was revealed that the gait periods of the left hemiparetic individuals are more asymetric than that of the right hemiparetic individuals. The cadence and gait speed of hemiparetic individuals decreased when compared to healthy individuals, and their walking period time increased. While the stance phase period of especially left hemiparetic individuals on the hemiparetic side decreased when compared to the healthy individuals, their swing phase period increased. Regarding the pelvis movements, pelvic tilt, pelvic obliquity, pelvic rotation symmetry, pelvic obliquity angle and pelvic rotation angles of the hemiparetic individuals decreased, and pelvic tilt angles increased when compared to the healthy individuals.

According to the World Health Organization, one-third of 15 million individuals with strokes every year have permanent walking problems causing functional dependence in daily life, and in-society ambulation restrictions create permanent impairment (available at: https://acikerisim.konya.edu.tr/xmlui/handle/20.500.12452/5452). A study showed that the patients could not walk at the beginning, and only 15% of them could walk independently even after having rehabilitation. Although walking ability could be gained in 60% of hemiparetic individuals, the inability to form a functional walking period causes limitations in in-society ambulation [11].

The right and left hemispheres differ from each other in their specialized functions. For this reason, lateralization of the lesion causes different symptoms in patients [12]. In their study, Lopes et.al. expressed that motor activities, requiring planning and coordination, are controlled by the left hemisphere, and the sensorimotor data critical for sitting, standing and protecting the posture are integrated by the right hemisphere [13]. As a result of this study, it was found that the walking symmetries of right and left hemiparetic individuals distort when compared to the healthy individuals, and walking in left hemiparetic patients is more asymmetric.

In the study conducted by Adıgüzel et.al. in which the impact of lateralization on balance and walking has been assessed in hemiparetic individuals, it was detected that left hemiparetic individuals were better at balance scores and 50-step walking tests, but there was no significant difference between them when compared to right hemiparetic individuals (available at: https://acikerisim.deu.edu.tr/xmlui/handle/20.500.12397/9887). In the study conducted by Polat in 2009, it was supported with the finding that there was no difference between gait parameters of right and left hemiparetic individuals (available at: https://acikerisim.konya.edu.tr/xmlui/handle/20.500.12452/5452). In parallel with other studies, in this study, it was found that the gait speed, cadence, double support and single support period times of right and left hemiparetic individuals were similar.

Gama found that right hemiparetic individuals are more asymmetrical in swing phase compared to left hemiparetic individuals. However, he has found results similar to the literature that there was no difference in speed, stride length, stance in both extremities and swing phase, maximum hip flexion, knee flexion and extension and foot dorsiflexion [13, 14]. In this study, results similar to those of Gama were attained in speed, cadence, stride length, stance in both extremities and swing phase, as well as the fact that left hemiparetic individuals have more asymmetrical walking.

In the study conducted by Titianova et.al. comparing walking parameters in hemiparetic and healthy individuals, there was a decrease in speed, stride length and swing phase period, and an increase was observed in the stance phase and double support period time [15]. The study by Carmo et al. supports previous studies with similar results [16]. Results in parallel to the previous studies have been found in this study by finding a decrease in the cadence, speed and stride length in hemiparetic individuals. At the same time, an increase was detected in the hemiparetic side swing phase and double support phase periods, and a result different from the literature was found. The reason for this difference makes us think that it may stem from the decrease in sensory awareness on the hemiparetic side and the increase in the motor ignition period of the muscles forming the movement.

The fact that the body balance center oscillation is above normal in the hemiparetic individuals causes a compensatory overload in the pelvis during walking [17,18]. In the study conducted by Little et.al., it has been specified that the abnormalities in pelvis movements in individuals with stroke cause walking disorders [18]. In another conducted study, it has been determined that the pelvic tilt symmetries of hemiparetic and healthy individuals are similar, but the pelvic tilt amplitude of hemiparetic individuals has increased [19]. It has been determined in this study that the pelvic tilt angles of hemiparetic individuals have increased. Besides, in contrast to the conducted studies, the results of this study have revealed that the pelvic tilt symmetries decrease in hemiparetic individuals.

When the walking and pelvis movement in hemiparetic individuals are compared in respect to lateralization; while right hemiparetic individuals have a more symmetrical walking, they have more asymmetrical pelvis movement. It is considered that these results occur due to the impact of dominant hemisphere on walking.

The strong side of this study is that it has been conducted as based on objective data. Taking also lateralization into consideration in the comparison of the hemiparetic and healthy control groups is valuable in terms of attaining objective results depending on the direction of influence. Selection of the demographic data of the individuals in a homogenous way while determining the study and control groups and the inclusion of individuals below 65 terminates the impacts of personal data in this study. Consideration of the hemiparesis period decreases the impact of the individuals having rehabilitation on the results. Moreover, the examination of pelvis movements in this study is significant due to its impact on walking parameters.

The weak sides of this study are that etiology is not uniform and the inclusion of those that could walk with walking aids in the study. As well as objective assessment, conducting the evaluations with the fixation of walking speed, sequence and periods of muscle spasms and foot compression changes will provide opportunities for a better understanding of the differences in walking in future studies.

The results of the study show that lateralization has an impact on the difference in terms of walking symmetry in the right and left hemiparetic individuals during walking, but it does not have any impact on the other parameters of walking. Furthermore; right and left hemiparetic individuals have influences in terms of walking parameters when compared to healthy individuals. The reason for these results clearly indicates that hemiparesis affects walking and lateralization has an impact on walking.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

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 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

Funding: *None*

Conflict of interest

None of the authors received any type of financial support that could be considered potential conflict of interest regarding the manuscript or its submission.

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How to cite this article:
Gulsum Tıkac, Filiz Altug, Ayse Unal. Investigation of the spatio-temporal gait parameters in individuals with hemiparesis: The effect of lateralization. Ann Clin Anal Med 2021; DOI: 10.4328/ACAM.20643