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Original articles

The Effects of Initiation Side on Gait Symmetry in the Stroke Patients

Hwa-Kyung Shin[1], Dae-Yong Noh[2]

[1]Department of Physical Therapy, College of Medical Science, Catholic University of Daegu, [2]Department of Physical therapy, Graduate school of medical science, Catholic university of Daegu

Purpose: To investigate the effects of initiation side on gait symmetry in the chronic stroke patients.

Methods: Twenty one patients with independent gait after stroke were divided into the paretic-leg gait initiation group (PLI) and the nonparetic-leg gait initiation group (NPLI). The symmetry ratio (SR) was calculated from of the spatiotemoral and kinematic parameter which measured by 3D motion analysis.

Results: In the spatiotemporal variables, SR-step length and SR-velocity was significantly different between groups ($p<0.05$). In the kinematic variables, SR-TOAA and SR-SwPAA of the hip joint was significantly different between groups ($p<0.05$).

Conclusion: We suggest that the initiating leg may influence on the gait symmetry of stroke patient These results will be a helpful reference in hemiplegic gait training or intervention.

Key Words: Gait initiation, Motion analysis, Stroke, Symmetry

Ⅰ. Introduction

Damaged gait function reduces the functional independence of a hemiplegic patient in everyday life motions, and lowers the quality of life of the patient[1]. One of the important characteristics of the abnormal gait of a hemiplegic patient is the asymmetry of the paretic and nonparetic sides[1]. Asymmetric characteristics can make a hemiplegic patient's gait initiation harder. The gait initiation process is commonly thought to be an unconsciously occurring simple movement, but it is actually made complex by the integration of numerous nerves and biodynamic power[2]. Thus, a patient who loses his or her gait ability will find gait initiation more difficult. For hemiplegic patients, the paretic leg supports less than 50 % of the entire weight, and the nonparetic leg approximately 80 %. Thus, at the time of gait initiation, the weight is placed on the nonparetic leg rather than on the paretic leg, and initiates the paretic foot. As such, in many cases, hemiplegic patients have an asymmetric gait[3,4].

The process in which a hemiplegic patient takes the first step in gait is very important. It is the process in which the balance maintained by both legs is shifted to one leg, and then the remaining leg is lifted[4]. A stroke patient initiates gait more cautiously compared with a healthy adult, due to the stroke patient's lowered balance control, and leans his or her trunk towards the side, showing a clearly different gait from that during gait initiation[5]. The stroke patient's gait initiation develops into an asymmetrically adapted posture–movement strategy to compensate for the damage, and is conducted strategically, with personally adapted patterns.

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Corresponding author Hwa-Kyung Shin, hkshin1@cu.ac.kr

The pattern that becomes a regular habit is formed either through personal adaptation or repetitive gait training, and most patients initiate gait using the adapted methods. For this reason, gait initiation training is considered very important[6,7].

When a hemiplegic patient initiates gait, the symmetric weight load is related to the anterior propulsion at the time of gait[8]. Henriksson et al. reported in their researches on the prevention of falling that the weight load and the vitality of the muscles of the ankle change with aging, and that this leads to changes in gait initiation[9]. Bensoussan et al. reported in their analysis of hemiplegic gait initiation patterns that when supported by the paretic leg, the single-leg-stance phase is shorter; that anterior propulsion occurs when supported by the nonparetic leg; that the angle of the ankle is higher, with compensation for the foot, when the paretic leg is in the swing phase; and that the paretic leg shows the form of platypodia at the first ground connection[10]. Thus, researches on the general characteristics of the gait initiation of stroke patients have been reported, but researches comparing the gait characteristics of chronic stroke patients to determine their adapted gait patterns by distinguishing between the paretic and nonparetic legs are rare. As such, in this research, the effects of stroke patients' adapted order of gait initiation on the gait symmetry of the paretic and nonparetic legs were determined, and basic data were obtained that can be used for gait training.

II. Methods

1. Subjects

The subjects in this research were 21 chronic stroke patients who have had hemiplegia caused by cerebral hemorrhage or cerebral infarction for more than one year at the time that the study was conducted, who could walk independently without a prosthetic leg, who had K-MMSE scores of more than 24 points, and who had no cognitive-function and communication problems and no other neurological or orthopedic diseases. The subjects were divided the group with paretic-leg initiation (PLI) and, the group with nonparetic-leg initiation (NPLI). We decided the initiation leg as the leg which initiate more than 7 times of 10 trials for a week before experiment. Adapted gait initiation foot refers to the gait initiation swing leg of the subjects when the sign of gait initiation was given at the posture characterized by aligned feet.

2. Experiment instruments procedure

For the analysis of the subjects' gaits, the motion analysis capture system, a three-dimensional motion analyzer, was used. It consists of a total of eight Eagle infrared cameras in a motion analysis laboratory, and is 3D optical tracing equipment that records the motion capture that appears from the manual indicator's movement (Motion Analysis, USA). Helen Hayes maker set with 19 static trials markers included Left ASIS, Right ASIS, Sacrum, Left thigh wand, right thigh wand, left lateral knee, right lateral knee, left shank wand, right shank wand, left lateral knee, right lateral knee, left heel, right heel, left toe, right toe, Left medial ankle, right medial ankle, left medial knee, right medial knee.

Spatiotemporal variables included Step length, Stride length, Velocity, Stance phase, Swing phase, Double support phase, and SW/ST. Kinematic variables included average foot strike angle, average stance phase angle, average toe off angle, and average swing phase angle in the sagittal plane of hip, knee, and ankle joint.

The subjects' gaits were captured real-time and were edited using EVaRT(version 5.0.5, Motion Analysis Corp, Santa Rosa, CA, US). The data obtained from EVaRT using Orthotrak (version 6.6.1, Motion Analysis Corp, Santa Rosa, CA, US) were then processed and analyzed. Recurrent reflexive indicators were attached to the subjects through the Helen-Hayes method, to obtain the spatiotemporal data of the subjects' gaits. The same skilled examiner attached the indicator to all the subjects, and the subjects were barefoot during the examination. The subjects were made to walk at a comfortable speed and posture to warm-up for about 3 minutes. They were then made to walk at a distance of about 3 meters with their adapted comfortable gait upon hearing a beeping sound (the initial sound of the motion capture program), after training to adapt to the laboratory

Table 1. General characteristics of subjects

	paretic leg-initiation (N=11)	nonparetic leg-initiation (N=10)
male/female	8/3	5/5
paretic side (Lt/Rt)	7/4	4/6
age (yrs)	57.50 ± 10.43	57.90 ± 6.40
onset (yrs)	6.37 ± 2.33	5.10 ± 2.13
height (cm)	167.30 ± 6.03	163.40 ± 7.56
weight (cm)	67.27 ± 8.29	62.20 ± 10.78
foot length (cm)	25.86 ± 1.09	24.80 ± 1.36
foot width (cm)	10.32 ± 0.51	10.00 ± 0.81

Table 2. Comparison with symmetryical ratio of spatiotemporal parameter between groups

	paretic leg-initiation	Non-paretic leg-initiation	t	p
Step length	1.58 ± 0.65	0.87 ± 0.30	3.23	0.01*
Stride length	1.01 ± 0.05	1.02 ± 0.04	-0.42	0.68
Velocity	0.96 ± 0.02	1.07 ± 0.89	-3.59	0.01*
Stance phase	0.84 ± 0.08	0.80 ± 0.08	1.00	0.33
Swing phase	1.50 ± 0.23	1.64 ± 0.28	-1.31	0.21
Double support phase	1.01 ± 0.29	1.14 ± 0.45	-0.75	0.46
SW/ST	1.83 ± 0.50	2.10 ± 0.54	-1.21	0.24

*P<0.05

environment. After measuring the gait about five times, the mean of three intact data values was calculated and was used for the analysis.

After the calculation of the gait symmetry ratio (SR) of the paretic and nonparetic legs, using spatiotemporal variables, following the analysis of each subject's gait, the differences between the two groups were determined. The formula of SR is as follows[12].

Symmetry ratio = paretic side / non–paretic side

when the symmetry ratio was 1, the paretic and nonparetic legs had complete symmetry, but the farther away from 1 the value became, the more asymmetric the legs became. When the symmetry ratio was higher than 1, the paretic leg's value was higher than that of the nonparetic leg, and when the symmetry ratio was lower than 1, the paretic leg's value was smaller than that of the nonparetic leg.

Independent t–tests were used to compare the SR of spatiotemporal parameters and kinematic parameters between the 2 groups. Statistical significance was set at $p<0.05$, and all analyses were performed using SPSS version 18.0 software (SPSS Inc, Chicago Illinoise).

III. Results

General characteristics were not significant difference between PLE group and NPLE group (Table. 1). In the Spatiotemporal variables, SR–step length in the NPLI group (0.87±0.30) was less than one, while that of the PLI group (1.58 ±0.65) was greater than one. SR–gait velocity in the NPLI (1.07±0.89) was greater than one, while that of PLI group (0.96 ±0.02) was less than one. SR–step length and SR– was significantly different between groups ($p<0.05$).

Table 3. Comparisons with joint kinematics between groups in sagittal plane

		paretic leg-initiation	nonparetic leg-initiation	t	p
Hip	FSAA	0.78 ± 0.19	0.66±0.14	1.59	0.13
	StPAA	0.88 ± 0.23	0.72±0.15	1.93	0.07
	TOAA	1.09 ± 0.39	0.75±0.20	2.46	0.02*
	SwPAA	0.90 ± 0.19	0.73±0.09	2.77	0.01*
Knee	FSAA	0.69 ± 0.37	0.52±0.38	1.04	0.31
	StPAA	0.53 ± 0.18	0.43±0.36	0.86	0.40
	TOAA	0.59 ± 0.20	0.47±0.19	1.44	0.17
	SwPAA	0.61±0.22	0.51±0.25	0.95	0.36
Ankle	FSAA	0.44±0.27	0.39±0.37	0.38	0.71
	StPAA	0.55±0.23	0.48±0.22	0.65	0.52
	TOAA	0.44±0.26	0.47±0.47	-0.20	0.84
	SwPAA	0.44±0.31	0.40±0.28	0.31	0.76

*p<0.05
FSAA : foot strike angle average
StPAA : stance phase angle average
TOAA : toe off angle average
SwPAA : swing phase angle average

In the kinematic variables, SR–TOAA of hip joint in NPLI group (0.75±0.20) was less than one, while that of PLI group (1.09 ±0.39) was greater than one. SR–SwPAA of hip joint in the NPLI group (0.73 ±0.09) was more far from one, while than that of PLI (0.90 ±0.19) was less than one. SR–TOAA and SR–SwPAA of the hip joint was significantly different between groups (p<0.05).

IV. Discussion

For the patients who can walk independently to a certain extent, with their own gait strategies and patterns, the order of gait initiation is formed by their own adaptation or through gait training[11]. Thus, it is very important for hemiplegic patients to precisely grasp their gait characteristics. In this research, the effects of the order of gait initiation in people with hemiplegia due to stroke on the spatiotemporal variables of gait, and the symmetry of the joints' angles in the sagittal plane, were examined.

As for the symmetry ratio of the spatiotemporal variables, there were significant differences in stride and speed between the two groups. If the fact that the perfect symmetry is 1 according to the symmetry ratio formula is taken into account, the PLI group means that the paretic leg's stride is longer, showing the same appearance as the patients in the past researches. In the NPLI group, the nonparetic leg's stride was longer, and the nonparetic leg showed a different appearance from that of the stroke patients in the past researches. There were significant differences in the symmetry ratio of gait speed between the PLI and NPLI groups. In other words, in the case of the NPLI group, the paretic leg's speed was found to be higher, and the paretic leg showed a different appearance from that of the existing stroke patients. In the hemiplegic patients' gait, the paretic leg's stance phase decreased, and the swing phase relatively increased. Due to these phenomena, the symmetry ratio of the stance phase was found to be 1 or less in both groups, and that of the swing phase was found to be 1 or higher. Moreover, there were no significant differences in the symmetry ratios of the stance and swing phases between the PLI and NPLI groups. As for SW/ST, the symmetry ratios were greater than 1 in both groups, and there were no significant differences between the groups.

To examine the symmetry of the cinematic indicators, in the sagittal plane, where the degree of changes at the time of gait is relatively high, the symmetry ratios of the flexion angle of the hip knee, and ankle joints were calculated and compared. In the buttock joints, the symmetry ratios of the TOAA and SWPAA were significantly higher in the PLI group than in the NPLI group. On the other hand, for FSAA and StPAA, the symmetry ratio was found to be higher in the PLI group than in the NPLI group, but there were no statistically significant differences between the two groups. The symmetry ratios of the flexion angles of the ankle joints were found to be relatively lower than those of the other joints, and in all the sections, except for TOAA, the symmetry ratio was found to be higher in the PLI group than in the NPLI group, but there were no statistically significant differences between the two groups.

The asymmetric gait of hemiplegic patients is caused by their inability to shift the weight center to the paretic leg[12,13]. There have been many researches that compared and analyzed the gait variables fragmentally to determine the characteristics of the gait of stroke patients, but there have been few researches that attempted to quantify such variables by comparing the degree of coincidence of the paretic and nonparetic legs[14]. Alexander LD et al. represented the differences in the spatiotemporal gait variables measured in the paretic and nonparetic legs to express the distinguishing gait characteristics as an asymmetry ratio, and compared them, and Patterson et al. reported that the symmetry ratio is effective in representing the symmetry of people with hemiplegia due to stroke[12,15]. One of the ideal goals of functional gait improvement is to lower the degree of asymmetry. In the researches conducted by Patterson et al., the symmetry ratios of the spatiotemporal indicators in the group of normal people were found to be 1.02–1.04, which are close to 1, representing perfect symmetry. When the differences from 1 (the perfect symmetry value) were compared in this research, the PLI group, on the whole, was considered to be symmetric in gait. In the gait training of hemiplegic patients who have clear asymmetric differences, the therapeutic aim should be to achieve a more symmetric gait form. Thus, the results of this research show that it is more efficient to initiate gait with the paretic leg. In this research, the characteristics of the symmetry ratio of gait according to the order of the foot that initiates gait were shown. The data obtained in this research are considered important basic data for gait training for the functional rehabilitation of stroke patients. As the number of research subjects was small, however, it is difficult to generalize the results of the research, and such results cannot be compared with the corresponding data from normal people. For the future study, a sufficient number of subjects should be secured. Moreover, it is considered necessary to do research on the symmetry not only of gait but also of other functional movements.

In this research, the effects of the order of the adapted gait initiation foot of people with hemiplegia due to stroke on the gait symmetry were examined. The research results showed that it was more efficient in asymmetry to initiate gait with the nonparetic leg. It is expected that the results of this research can serve as basic data for gait training or mediation for stroke patients.

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References

1. Brunt D, Vander Linden DW, Behrman AL. The relation between limb loading and control parameters of gait initiation in persons with stroke. Arch Phys Med Rehabil. 1995;76(7):627–34.
2. Chen G, Patten C, Kothari DH et al. Gait deviations associated with post-stroke hemiparesis: Improvement during treadmill walking using weight support, speed, support stiffness, and handrail hold. Gait Posture. 2005;22(1):57–62.
3. Dawson M, Reiter F, Sarkodie-Gyan T et al. Gait initiation. Development of a measurement system for use in a clinical environment. Biomed Tech (Berl). 1996;41(7–8):213–7.
4. Forczek W, Staszkiewicz R. An evaluation of symmetry in the

lower limb joints during the able-bodied gait of women and men. J Hum Kinet. 2013;35(1):47-57.
5. Henriksson M, Hirschfeld H. Physically active older adults display alterations in gait initiation. Gait Posture. 2005;21(3):289-96.
6. Hesse S, Reiter F, Jahnke M et al. Asymmetry of gait initiation in hemiparetic stroke subjects. Arch Phys Med Rehabil. 1997;78(7):719-24.
7. Kim SH, Choi JD. The effects of gait training of progressive increasing in body weight support and gait speed on stroke patients. J Korean Soc Phys Ther. 2013;25(5):252-9.
8. Campbell FM, Ashburn AM, Pickering RM et al. Head and pelvic movements during a dynamic reaching task in sitting: Implications for physical therapists. Arch Phys Med Rehabil. 2001;82(12):1655-60.
9. Henriksson M, Henriksson J, Bergenius J. Gait initiation characteristics in elderly patients with unilateral vestibular impairment. Gait Posture. 2011;33(4):661-7.
10. Bensoussan L, Mesure S, Viton JM et al. Kinematic and kinetic asymmetries in hemiplegic patients' gait initiation patterns. J Rehabil Med. 2006;38(5):287-94.
11. Winiarski S, Czamara A. Evaluation of gait kinematics and symmetry during the first two stages of physiotherapy after anterior cruciate ligament reconstruction. Acta Bioeng Biomech. 2012;14(2):91-100.
12. Patterson KK, Gage WH, Brooks D et al. Evaluation of gait symmetry after stroke: A comparison of current methods and recommendations for standardization. Gait Posture. 2010;31(2):241-6.
13. Tokuno CD, Eng JJ. Gait initiation is dependent on the function of the paretic trailing limb in individuals with stroke. Gait Posture. 2006;24(4):424-8.
14. Ko M, Bishop MD, Behrman AL. Effects of limb loading on gait initiation in persons with moderate hemiparesis. Top Stroke Rehabil. 2011;18(3):258-68.
15. Alexander LD, Black SE, Patterson KK et al. Association between gait asymmetry and brain lesion location in stroke patients. Stroke. 2009;40(2):537-44.