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Changes of spatio-temporal gait parameters according to experience falls in post-stroke patients

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Objective: Falls are defined as contact of the body with the floor after losing balance during activities of daily living. Falls commonly occur among the elderly, and stroke patients in particular are at a high risk of falling. The purpose of this study was to investigate the changes of temporal and spatial gait parameters and gait symmetry according to experience falls in post-stroke patients.
Design: Cross-sectional study.
Methods: Fifty three patients with stroke were recruited on a voluntary basis from the rehabilitation unit, who currently undergoing physical therapy. All participants were asked to answer questions regarding the frequency of falls in the past 1 year. Fifty-three patients with stroke were allocated 2 groups according to experienced falls: stroke with falls (n=26) during past 1 year and stroke without falls (n=27). The spatial and temporal gait parameters and gait symmetry ratio were measured using GAITRite system.
Results: The spatial gait parameters and the temporal gait parameters were significantly different between the stroke with falls group and the stroke without falls group ($p < 0.05$). Furthermore, step length was the only significantly different among symmetry ratio ($p < 0.05$).
Conclusions: Experience of falls can lead to impairment of gait ability in stroke patients. This result is expected to be used as a basic data for rehabilitation program development to prevent a fall of post-stroke patients.

Key Words: Fall, Gait, Stroke

Introduction

Falls are defined as contact of the body with the floor without external impact shocks after losing balance during the process of activities of daily living (ADL) [1]. A fall occurs across the whole process of a life, especially frequently for the elders more than 65 years old. It increases gently after 75 and reaches the climax between the ages of 80 to 84 range, and the survival and frequency reduce for more than 85 as there are often restrictions on activities [2].

A fall is caused by complex interactions of several factors rather than one factor [3]. The main factors known to frequently contribute to a fall are increases of the loss of lower extremity strength which occur as one gets older, increase in postural sway which comes from decrease of muscle power supporting knees, and a decrease in stride length, reduction in walking speed, reduction of toe off and increase of double limb support period [4], and other factors are reported to also causes a fall are various ones such as environmental factors, psychological factors, pathological factors, etc [5]. In particular, because stroke patients show decreases in postural control, activities of daily living and mobility caused by various neurologic damages [6], such as caused by motor disorder, sensory disorder, cognition disorder, perception these accidents are reported to be included in a high risk of falling [7]. A fall of stroke patients leads to a restriction of activities and

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life-dependent pattern, so various studies were conducted to understand and prevent patterns of a fall [8].

Hyndman and Ashburn [9] reported a cross-sectional study which recruited forty-eight mobile community-dwelling people with stroke to identify relationships between stroke patients' attention, balance, function and a fall, a significant difference in balance and ADL ability between repeat-fallers and non-fallers, and, Mansfield *et al*. [10] reported a significant relationship between motor impairment, postural sway, a fall experience and limb center of pressure synchronization was demonstrated.

For stable and independent walking for stroke patients, sufficient stance stability, rhythmic muscle activation pattern, and sufficient mechanical energy on an even surface are necessary, and the ability to adapt to environmental obstacles and constraints on an uneven surface is required [11].

Among stroke patients, gait patterns can differ from one another, but there are certain characteristics of gait of stroke patients which appear in general [12]. For example, these characteristics are decrease in gait cycle and walking speed due to timing, muscle hypertension, changes in mechanical property of soft tissue, and difference between paretic step length and non-paretic step length. Also, the characteristics include an asymmetrical gait pattern such as long stance phase and relatively short swing phase of paretic side [13]. These gait characteristics causes a clear difference of spatial and temporal gait parameters when compared to normal subjects [14], and increases energy consumption and decreases walking speed and endurance [15]. Furthermore, through various studies, it was found that when walking in complex environments such as a shopping mall, resolution of additional cognitive task degrades postural control by influencing gait parameters like walking speed, step and stride length, and double limb support period [16,17].

Despite that stroke patients' gait patterns from neurologic damages have potential to be connected to falling accidents [18], the studies addressing gait of stroke patients with experience of falling is deficient.

There is a previous study of comparison between stroke patients and nondisabled elderly people, which revealed that stroke patients have slower walking speed than nondisabled elderly people do [19], but nor a direct study regarding changes in temporal and spatial gait parameters caused by stroke patients' experience of falling, nor a research about gait symmetry which is identifiable from temporal and spatial parameters of gait [20] is being conducted.

Thus, the purpose of this study was to investigate the changes of temporal and spatial gait parameters and gait symmetry according to experience falls in post-stroke patients.

Methods

Subjects and procedure

Subjects of this study are those who understand and agree to participate in this test among patients who are diagnosed with stroke in Korea Seoul Bukbu hospital rehabilitation medicine and currently have standard rehabilitation. All participating subjects were asked to answer questions regarding frequency of falls in the past one year [21], in which fall was defined as any unplanned, unexpected contacts with a supporting surface (ground, chair, wall, step, etc.) [22]. The subjects were divided into a 26-patient falls stroke group and a 27-patient non-falls stroke group.

Subjects were recruited according to the following inclusion criteria: Mini-Mental State Examination [23], hemiparetic from a single stroke occurring at least six months earlier. able to walk 10 m independently without an assistive device, no known musculoskeletal conditions that would affect the ability to safely walk repeatedly, and absence of serious visual impairment or hearing disorder.

Outcome measures

Gait abilities were measured using an electrical walkway system (GAITRite, CIR System Inc., Clifton, NJ, USA). The system captures temporal and spatial gait parameters and connects to the serial port of a personal computer. It consists of an 810×89×0.625 cm (length×width×height) instrumented mat with 27,648 embedded pressure sensitive sensors spaced at 1.27 cm arranged in a 48×576 grid. The sampling rate was 80 Hz and the obtained data were analyzed using gait analysis software (GAITRite GOLD, ver. 3.2b, CIR System Inc., Clifton, NJ, USA). Subjects walked at their comfortable gait speed over 3 trials. Subjects initiated and terminated walking a minimum of 5 m from the start and end of the walkway to maintain the gait speed on the mat. A verbal command was given to initiate walking and one of the examiners accompanied the subject to prevent a fall during walking. Gait velocity, cadence, step length, stride length, single limb support and double limb support for both the affected and unaffected legs, and gait symmetry ratio were measured. Gait symmetry ratio were quantified using an index proposed by Patterson *et al*.

[24].

The formula is as follows:

$$\text{Gait symmetry ratio}=\frac{\text{paretic side (parameter valru)}}{\text{non-paretic side (parameter valru)}}$$

Data analysis

Statistical analyses were performed using SPSS ver. 15.0 software (SPSS Inc., Chicago, IL, USA). After confirming the normality of the data by using the Shapiro-Wilks test, General characteristics comparisons between groups were examined with independent t-test and chi-squared test. Changes of spatial and temporal gait parameters and differences of symmetry ratio were examined with independent t-test between groups comparison. The level of significance was chosen as 5% for all statistical analyses.

Results

No significant differences in general characteristics at inclusion were detected between groups (Table 1). The spatial gait parameters (velocity and cadence) and the temporal gait parameters (step length, stride length, sing limb support period, and double limb support period for both the paretic and non-paretic legs) were significantly different between the fall stroke group and the non falls stroke group (Tables 2, 3) ($p < 0.05$). In additional, step length was the only significantly different among symmetry ratio (Table 4) ($p < 0.05$).

Discussion

Stroke patients with fall experiences are more likely to be exposed to hip fracture, Loss of independent mobility, and severely death than stroke patients without fall experience, so it is important to prevent a fall and assess correct mobility in a stage before post stroke [25]. In a clinic, reliability and validity are demonstrated to assess the gait ability of stroke patients, and 10 m walking test and Timed Up and Go test are mainly used for judging a degree of impairment from a stroke as the tests are closely correlated to a degree of damage [26]. However, the assessment has disadvantages of being likely to be interrupted by subjective judgments, not being able to find subtle changes and disability of quantitative assessment which is necessarily required for understanding pathological gait [11].

Table 2. Differences of temporal gait parameters

Parameters	Stroke with falls (n=26)	Stroke without falls (n=27)	t
Velocity (cm/sec)	41.45 (13.98)	65.69 (18.87)	-5.328***
Cadence (step/min)	69.05 (20.52)	90.35 (16.79)	-4.141***

Values are presented as mean (SD).
***$p < 0.001$.

Table 1. General characteristics of the subjects

Parameters	Stroke with falls (n=26)	Stroke without falls (n=27)	t	*p*
Gensder				
Male	16 (61.5)	15 (55.5)	0.195	0.659
Female	10 (38.5)	12 (44.5)		
Paretic side				
Left	8 (30.7)	5 (18.5)	1.074	0.300
Right	18 (69.3)	22 (72.5)		
Etiology				
Infarction	16 (61.5)	19 (70.3)	0.461	0.497
Hemorrhgic	10 (38.5)	8 (29.7)		
Medications				
Anti-hypertensive	11 (42.3)	13 (48.1)	0.182	0.669
Anti-depressants	7 (26.9)	8 (29.6)	0.048	0.827
Height (cm)	163.21 (8.89)	163.00 (7.15)	0.096	0.924
Weight (kg)	62.34 (8.05)	61.16 (9.19)	0.494	0.623
Stroke duration (day)	496.03 (129.25)	515.62 (175.95)	-0.460	0.648
Age (yr)	64.88 (6.63)	62.62 (6.30)	1.268	0.210
MMSE (scores)	26.38 (2.66)	25.1 (1.92)	1.997	0.053

Values are presented as n (%) or mean (SD).
MMSE: Mini-Mental State Examination.

Table 3. Differences of spatial gait parameters

Parameters		Stroke with falls (n=26)	Stroke without falls (n=27)	t
Step length (cm)	P	38.07 (6.96)	44.07 (7.26)	-3.068*
	NP	32.19 (8.51)	42.35 (9.06)	-3.071*
Stride length (cm)	P	69.22 (14.07)	86.15 (15.04)	-4.094**
	NP	69.11 (15.24)	86.82 (15.61)	-4.093**
Single limb support period (%)	P	25.91 (6.75)	30.30 (5.08)	-2.679*
	NP	34.31 (5.40)	36.14 (3.61)	-2.665*
Double limb support period (%)	P	42.11 (9.05)	34.30 (6.41)	3.631**
	NP	42.22 (8.92)	34.24 (6.59)	3.712**

Values are presented as mean (SD).
P: paretic side, NP: non-paretic side.
*$p < 0.05$, **$p < 0.01$.

Table 4. Differences of symmetry ratio between groups

Parameters	Stroke with falls (n=26)	Stroke without falls (n=27)	t
Step length (cm)	1.25 (0.39)	1.05 (0.15)	2.410*
Stride length (cm)	1.00 (0.02)	0.99 (0.01)	1.695
Single limb support period (%)	0.75 (0.18)	0.84 (1.49)	-1.863
Double limb support period (%)	0.99 (0.04)	1.00 (0.04)	-0.507

Values are presented as mean (SD).
*$p < 0.05$.

Thus, in this study, changes in temporal and spatial gait parameters were identified by means of GAITRite system which is capable of objective and quantitative measurement in order to find a difference in gait ability between stroke patients with fall experience and stroke patients without fall experience.

The result of this study, the spatial gait parameters (velocity and cadence) and the temporal gait parameters (step length, stride length, sing limb support period, and double limb support period for both the paretic and non-paretic legs) were significantly different between the fall stroke group and the non falls stroke group (p<0.05) (Figures 1, 2).

Experience of a fall brings fear of falling, which causes limitation of activity due to loss of confidence and dependent life, and decrease of gait stability is reported as a main risk factor of a fall [27], van Haastregt *et al*. [28] reported that fear of falling leads to anxiety, depression, and increase of avoidance activities. In this study, the memory of stroke patients with fall experience about a fall is believed to work as fear and cause decrease in gait stability decrease and avoidance movement, having an influence on the decrease of temporal and spatial gait ability.

The causes of a fall are largely divided into intrinsic factors (muscle weakness, poor balance ability) and extrinsic

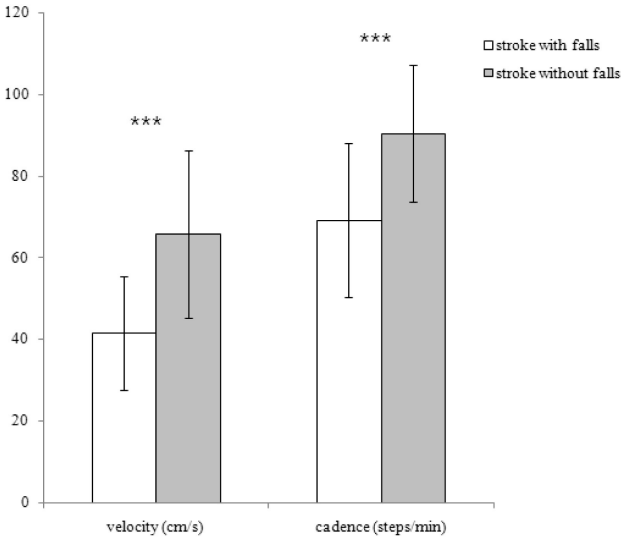

Figure 1. Differences of temporal gait parameters in stroke patients with and without fall experience. ***$p < 0.001$.

factors (doses of various drugs, environmental changes), and psychological factors are also reported to be the factor of occurrence of a fall [5]. But, as this study lacked in investigation of psychological factors in its subjects, future studies are expected to complement these parts.

For stroke patients, increase of gait ability is an ultimate

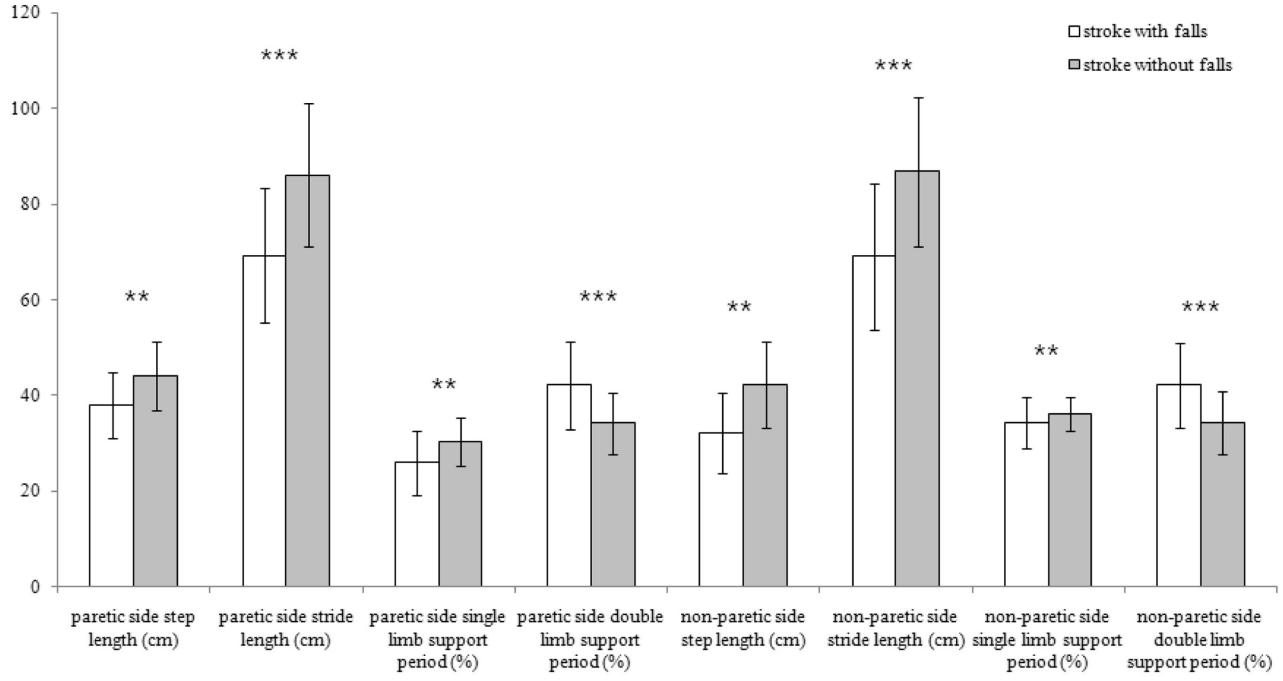

Figure 2. Differences of spatial gait parameters in stroke patients with and without fall experience. $^{**}p < 0.01$, $^{***}p < 0.001$.

goal of rehabilitation, which focuses many researchers' great attention on assessment and improvement of walking speed [29]. However, it is limited in both its value to document post-stroke recovery and the information it provides regarding the underlying impairments [30]. In addition, gait velocity does not fully reflect all aspects of a typical stroke rehabilitation program and thus is limited as a solitary clinical measure to direct treatment and to reflect its outcomes [24]. Gait symmetry ratio is assessed in a manner of complementing this limitation. Gait symmetry ratio uses absolute value, and as ratio of the value get closer to 1, gait symmetry ratio increases, and as it gets far from 1, gait symmetry ratio decreases [31]. Thus, this study identified a difference in gait symmetry ration between stroke patients with fall experience and stroke patients without fall experience, and used the method of Patterson *et al*. [24] in order to get the gait symmetry ratio.

The results of this study, step length was the only significantly different among symmetry ratio ($p < 0.05$). In particular, step length symmetry ratio was higher as 1.25 cm than that of stroke patients with fall experience group as 1.05 cm, which showed asymmetry of step length. In case of asymmetry of gait, when stance starts to quickly move center of gravity to a non-paretic side, due to unstable paretic lower extremity, heel does not contact ground but sole or toe, which shortens stance phase of paretic side and a swing phase of non-paretic side, and forward propulsion becomes difficult, which causes a pattern where step length is shortened [29,32]. A direct comparison is not possible because there is no investigation on gait symmetry ratio of stroke patients caused by experience of a fall, but we believe that gait asymmetry by a fall, in particular, possibility of asymmetry of step length are significant results.

This study has a limitation that its targets was chronic stroke patients whose onset period in and out of 500 days and therefore the results may not be generalizable to stroke patients in the acute stage or to people who need assistance for ambulation. Thus, it is considered that further studies need to target various stages of stroke patients. In this study was to investigate the changes of temporal and spatial gait parameters and gait symmetry according to experience falls in stroke patients with experience falls and stroke patients without experience falls, our finding show that, the spatial and temporal gait parameters were significantly different between the stroke with falls group and the stroke without falls group. Furthermore, step length was the only significantly different among symmetry ratio. This result is expected to be used as a basic data for rehabilitation program development to prevent a fall of stroke patients.

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