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Impaired Dynamic Balance Is Associated with Falling in Post-Stroke Patients

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Falling is one of the most common complications of stroke. The purpose of this study was to investigate the impact of falling on cognitive and physical function in post-stroke patients. Further, the predictive factors associated with independence of activity of daily living (ADL) in stroke patients with falls experience were investigated. Sixty-six participants were divided into 2 groups according to history of falling: faller (n = 34) and non-faller (n = 32). All participants were examined for cognitive and physical function. Static balance was measured by postural sway using a force platform. Dynamic balance was measured using the Berg Balance Scale (BBS) and the Modified Rivermead Mobility Index (MRMI), which shows the degree of performance for balance tasks. ADL was measured using the Modified Barthel Index (MBI), which shows the degree of independence. The fallers showed lower cognitive and physical function than the non-fallers ($p < 0.05$). This finding indicates that falling is associated with reduced physical function, as well as reduced cognitive function. In the fallers, the ADL (MBI) was moderately correlated with each of cognition [MMSE ($r = 0.388$, $p = 0.023$)], dynamic balance [MRMI ($r = 0.514$, $p = 0.002$) and BBS ($r = 0.572$, $p < 0.000$)]. In addition, regression analysis showed that BBS was a primary predictor for ADL performance ($R^2 = 0.327$, $\beta = 0.572$, $p < 0.000$). Our findings indicate that enhancement of dynamic balance is needed to improve in activities necessary for normal self-care of stroke patients with falls experience.

Keywords: activities of daily living; balance; correlation; falls; stroke
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Introduction

Stroke patients generally appear motor dysfunction in terms of muscle tone (continuous and passive partial contraction of the muscles), reflexes (instantaneous movement in response to a stimulus), voluntary movement patterns (movements by their own will) and coordination (combination of body movements created with an action) (Prange et al. 2006). In particular, the impairment of motor function is the cause of the falls (Langhorne et al. 2009). Falls can lead to reduce the independence of activity of daily living (ADL) and patients become more dependent on care (Krebs et al. 2008). Thus, the ultimate goal of stroke rehabilitation is to prevent a fall and to reduce the degree of dependence for ADL, such as shopping, travel in community, housekeeping, and preparing meals, after returning to the community (Hyndman and Ashburn 2003; Gialanella et al. 2012).

Falling is one of the most common complications of stroke (Moroz et al. 2004), and many studies have reported that a fear of falling leads to a decrease in physical activity (Rapport et al. 1998; Suzuki et al. 2005). In addition, a recent study reported that experiencing a fall affected stroke patients' ADL performance (Czernuszenko and Czlonkowska 2009). Some studies have demonstrated that falls interfere with the functional recovery of stroke patients and restrict ADL performance (Nyberg and Gustafson 1997; Krishchiunas and Savitskas 2004). However, although it is known that stroke-related physical changes increase the risk of falling (Davenport et al. 1996), the relationship between these risk factors, especially cognitive and physical impairment, and falls experience is not well understood.

Many studies have been conducted to investigate the factors associated with ADL performance of stroke patients (Kim and Eng 2003; Cho and Lee 2012; Gialanella et al. 2012). In people with cognitive impairment, cognitive function cannot be used effectively to perform a meaningful task and is therefore closely related to impairment in ADL performance (Alladi et al. 2002). Many studies reported that cognitive impairment can reduce the independence for performing basic and instrumental ADL (Alladi et al. 2002; Cho and Lee 2012). Furthermore, Kim and Eng (2003)

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reported that the muscle strength of the paretic lower extremity was moderately to highly correlate with ADL performance in stroke patients. Another study reported that stroke severity and impaired balance are important restrictive factors of ADL performance (Gialanella et al. 2012). Although some factors associated with ADL performance of stroke patients are identified, the factors that can predict reduced independence of ADL in stroke patients with fall experience are still unclear.

Therefore, the purpose of the current study was to investigate the impact of falling on cognitive and physical function in post-stroke patients. In addition, relationships among cognitive and physical function in stroke patients with and without falls experience were investigated, and this study also investigate the predictive factors associated with independence of ADL in stroke patients with fall experience.

Subjects and Methods

Participants and procedures

This cross-sectional study used a retrospective analysis of patients records admitted to a rehabilitation department. Seventy-seven stroke patients admitted to a rehabilitation hospital between October 2011 and October 2012 were recruited. All participants were admitted to acute care wards for 3 weeks after the onset of stroke in order to stabilize their medical condition. Subsequently, the participants were admitted to a rehabilitation ward. All participants underwent conventional rehabilitation programs consisting of physical therapy, occupational therapy, and functional electrical stimulation (FES). Physical therapy was performed for 30 minutes per day, 5 times per week, during duration of hospitalization. Neurodevelopmental treatment (NDT) and proprioceptive neuromuscular facilitation (PNF) were conducted during the 30-minute session of physical therapy. NDT and PNF were conducted by skilled physical therapists with additional qualification in the PNF and Bobath techniques. Occupational therapy was performed for 30 minutes per day, 5 times per week, during duration of hospitalization. Occupational therapy consisted of task-specific repetitive functional training, strengthening, and motor control training using resistance to the patients' volitional movements. FES was applied simultaneously to the lower extremity for 20 minutes per day, 5 times per week, during duration of hospitalization. FES is a technique that uses electrical currents to activate nerves innervating extremities affected by paralysis due to neurological disorders. FES is primarily used to restore function in people with disabilities.

Participants with a previous history of dementia, significant difficulties in language expression or comprehension, presence of other neurological disease or confusion states, or the inability to provide informed consent were excluded. Initial screening was performed using a medical chart. Eleven participants (faller group: 6, non-faller group: 5) were excluded because of neurological disorders (n = 4), difficulties in language expression (n = 5), and the inability to provide informed consent (n = 2). Thus, 66 participants were included in the final analysis. The objectives and requirements of the study were explained to all patients, and they signed informed consent forms. The study was approved by the Kyungnam University Institutional Review Board.

Participants were asked to answer questions regarding the frequency of falls in the 1 year after the occurrence of stroke (Hyndman et al. 2002). However, because previous study has suggested that the participant's recall of fall history can produce bias (Peel 2000), we also confirmed the fall history information from a caregiver or spouse who was present. A fall was defined as any unplanned or unexpected contact of the body with a supporting surface (ground, chair, wall, step, etc.) (Chyu et al. 2010). The participants were divided into 2 groups according to their history of falls: faller (n = 34) and non-faller (n = 32) groups. The participant's characteristics are presented in Table 1.

The cognitive and physical functions of all participants were examined within the first week of admission. Cognitive function was evaluated using the Loewenstein Occupational Therapy Cognitive Assessment for Geriatric Populations (LOTCA-G) and Mini-Mental State Examination (MMSE). Physical function was evaluated as static balance, dynamic balance, and the level of ADL performance. Static balance was evaluated with postural sway velocity moment using the Good Balance Force Platform System. Dynamic balance was evaluated using the Berg Balance Scale (BBS) and Modified Rivermead Mobility Index (MRMI). In addition, the level of ADL performance was evaluated using the Modified Barthel Index (MBI). Three physical therapists (with 8, 10 and 12 years of experience, respectively) and 3 occupational therapists (with 7, 9 and 10 years of experience, respectively) who were blinded to the group assignment of the subjects, participated as examiners. The physical therapists evaluated BBS, MRMI, and the postural sway velocity moment, and the occupational therapists evaluated MMSE, LOTCA-G, and MBI.

Outcome measurements

Cognitive function: Cognitive function was evaluated using the LOTCA-G and MMSE. LOTCA-G is primarily used by occupational therapists to assess cognitive function after stroke and other brain injuries. The LOTCA-G provides information about the patient's abilities and deficiencies and about their capacity to cope with daily and occupational tasks (Katz et al. 1989). LOTCA-G consists of 7 major areas, containing 24 items. The areas investigated are orientation, perception, praxis, visuomotor organization, thinking operation, memory, attention, and concentration. Each subset is scored, and the total score ranges from 24 to 104. MMSE is used to screen for cognitive impairment in elderly or brain injury. The MMSE includes simple questions about problems in a number of areas: the time and place of the test, repeating list of words, arithmetic such as the serial sevens, language use and comprehension, and basic motor skills. MMSE evaluates the following 6 areas: orientation, memory, attention, calculation, language, and construction functions. The total score ranges from 0 to 30 (Mungas 1991). The examiners individually evaluated patient's cognitive function in a very quiet room to allow them to concentrate. The LOTCA-G and MMSE assessments took 30-40 and 10-15 minutes to complete, respectively.

Physical function: Physical function was evaluated as static balance, dynamic balance and the level of ADL performance.

Static balance was measured by postural sway velocity moment using a force platform (Good balance system, Metitur Ltd., Jyvaskyla, Finland) that measures postural sway generated by postural imbalance. When a subject stands on the symmetrically marked footprints on the force platform in relation to the midline (feet 20 cm apart and feet together), mean values (positive or negative) indicate the relative loading on the left and right legs, with a positive mean value indicat-

Table 1. General characteristics of the participants (n = 66).

	Faller group (n = 34)	Non-faller group (n = 32)	χ^2/t	P
Gender				
Male/Female	20/14 (58.8/41.2)*	24/8 (75.0/25.0)*	1.941	0.167
Paretic side				
Right/Left	20/14 (58.8/41.2)*	13/19 (40.6/59.4)*	2.184	0.139
Etiology				
Infarction/Hemorrhage	20/14 (58.8/41.2)*	20/12 (62.5/37.5)*	0.093	0.760
Walking ability				
Self / Walker / Cane	15/10/9 (44.1/29.4/26.5)*	11/8/13 (34.4/25.0/40.6)*	–	–
Age (*years*)	63.29 (11.54)#	65.40 (9.04)#	−0.824	0.413
Stroke duration (*days*)	639.44 (147.89)#	638.81 (122.64)#	0.019	0.985
Frequency of falls (*times*)	2.08 (0.83)#	–	–	–
Br stages (1/2/3/4/5/6)	0/3/10/14/4/3	1/2/17/8/2/2	–	–

*n (%), #mean (S.D.).

MAS, Modified Ashworth Scale; Br stages, Brunnstrom stages; 1, No activation of the limb; 2, Spasticity appears, and weak basic flexor and extensor synergies are present; 3, Spasticity is prominent, and the patient voluntarily moves the limb, but muscle activation is all within the synergy pattern; 4, The patient begins to activate muscles selectively outside the flexor and extensor synergies; 5, Spasticity decreases and most muscle activation is selective and independent from the limb synergies; 6, Isolated movements are performed in a smooth, well-coordinated manner.

Table 1 shows the general characteristics of the stroke patients who fulfilled the inclusion criteria for the study. There are no significant differences between the faller and non-faller groups.

ing a higher loading on the right leg (Era et al. 1996). To measure the postural sway velocity moment, subjects stood on the force plate with their legs spread at shoulder width, and then looked at a number on a monitor for 30 seconds. Each measurement was repeats 3 times, and the average value was used in the statistical analysis. In this study, the following instruction was communicated to the subjects to ask them to move their bodies as little as possible: "Please try your best to stand without swaying." This procedure was also repeated 3 times with the eyes closed. A 3-minute rest was provided between the measurements in order to prevent fatigue.

Dynamic balance was evaluated using BBS and MRMI. BBS is a valid and reliable instrument for measuring both the static and dynamic aspects of balance in elderly or stroke patients. BBS scores range from 0 to 56 points, and a higher score reflects better balance. The test takes 15-20 minutes and comprises a set of 14 simple balance related tasks, ranging from standing from a sitting position to standing on 1 foot. The results are based on the time taken to complete specific tests and how well the tests are performed. Each test is rated on a scale of 0 to 4 points (Berg et al. 1995). MRMI is a newly developed outcome measure that aims to evaluate the effectiveness of physical therapy on mobility following stroke. MRMI assesses 8 aspects of mobility ranging from turning over in bed to managing stairs. Lennon and Johnson (2000) tested the MRMI for face and content validity, and found that it had responsiveness (effect size = 1.15), test-retest reliability (r = 0.731), inter-rater reliability (ICC = 0.98), and internal consistency (Cronbach's alpha = 0.93).

The ADL performance level was evaluated using MBI. MBI is a measure of ADL, which shows the degree of independence of a patient. It covers 10 domains of functioning (activities): bowel control, bladder control, as well as help with grooming, toilet use, feeding, transfers, walking, dressing, climbing stairs, and bathing. (Mahoney and Barthel 1965). The scores of this scale range from 0 to 100 points, with a score of 100 points denoting complete independence. Each item receives a score from 0 to 15 points, reaching a total of 100 points for individuals who are sufficiently independent to perform ADL. Cronbach's alpha for a hemiplegia study was 0.84 (Mahoney and Barthel 1965).

Statistical analysis

All statistical analyses were performed using SPSS version 15.0 software. Descriptive statistics were used to evaluate the general characteristics of the subjects. An Independent t-test was used to compare differences between the 2 groups. Pearson's correlation coefficient was used to assess the relationship among variables in the faller and non-faller groups. Multivariate regression analysis was used to identify predictive factors related to the level of ADL performance in the faller group. Results were considered significant when p values were < 0.05.

Results

Comparison of variables between the faller and non-faller groups

The scores of MMSE (faller group: 15.58 vs. non-faller group: 20.96; $t = -2.610$, $p = 0.011$), LOTCA-G (faller group: 66.76 vs. non-faller group: 78.03; $t = -3.091$, $p = 0.003$), BBS (faller group: 26.35 vs. non-faller group: 36.37; $t = -3.290$, $p = 0.002$), MRMI (faller group: 26.76 vs. non-faller group: 32.65; $t = -3.286$, $p = 0.002$), and MBI (faller group: 51.14 vs. non-faller group: 64.81; $t = -3.292$, $p = 0.002$) were significantly lower in the faller group than in the non-faller group. Furthermore, the postural sway velocity moment with eyes open (faller group: 28.80 vs. non-faller group: 24.01; $t = 2.695$, $p = 0.009$) and closed (faller group: 39.17 vs. non-faller group: 34.82; t =

Table 2. Comparison of variables between the faller and non-faller groups (n = 66).

Parameters		Faller group (n = 34)	Non-faller group (n = 32)	t value	P value*
Cognitive function					
MMSE (*score*)		15.58 (6.79)	20.96 (6.49)	−2.610	0.011
LOTCA-G (*score*)		66.76 (17.90)	78.03 (17.10)	−3.091	0.003
Physical function					
Static balance	$PSVM_{EO}$ (mm^2)	28.80 (6.99)	24.01 (7.42)	2.695	0.009
	$PSVM_{EC}$ (mm^2)	39.17 (7.11)	34.82 (8.16)	2.308	0.024
Dynamic balance	BBS (*score*)	26.35 (14.34)	36.37 (9.82)	−3.290	0.002
	MRMI (*score*)	26.76 (8.58)	32.65 (5.53)	−3.286	0.002
ADL level	MBI (*score*)	51.14 (12.04)	64.81 (22.60)	−3.292	0.002

Values are expressed as mean (S.D.).

MBI, Modified Barthel Index; BBS, Berg Balance Scale; MRMI, Modified Rivermead Mobility Index; LOTCA-G, Loewenstein Occupational Therapy Cognitive Assessment for Geriatrics; MMSE, Mini-Mental State Examination; $PSVM_{EO}$, Postural sway velocity moment with eye open; $PSVM_{EC}$, Postural sway velocity moment with eye close.

**P* values are quoted for comparison between faller and non-faller groups.

Table 2 shows that cognitive function, dynamic balance, and ADL performance were significantly higher in the non-fallers compared to fallers. In addition, static balance was significantly lower in the non-fallers compared to fallers.

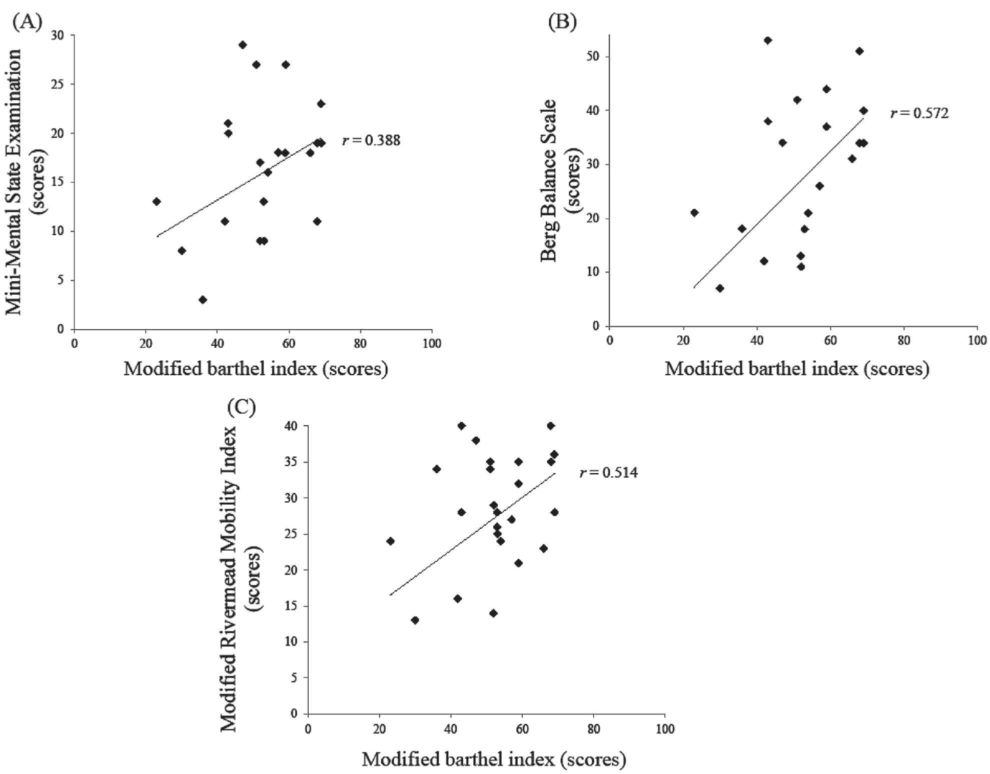

Fig. 1. Association between ADL performance and cognition and dynamic balance in faller group (n = 34).
Correlations between MBI and MMSE (r = 0.388, p = 0.023) (A), BBS (r = 0.572, p < 0.000) (B), and MRMI (r = 0.514, p = 0.002) (C) in post-stroke patients who had a history of falling. Correlation analysis indicates that ADL performance is positively correlated with cognition and dynamic balance function in stroke patients who had a history of falling.

2.308, p = 0.024) was significantly higher in the faller group than in the non-faller group (Table 2).

Correlations among each variable in the faller group

The correlations between variables in the faller group were as follows: MBI was moderately correlated with BBS (r = 0.572, p < 0.000), MRMI (r = 0.514, p = 0.002), and MMSE (r = 0.388, p = 0.023) (Fig. 1). BBS was moderately correlated with MRMI (r = 0.790, p < 0.000), MMSE (r = 0.652, p < 0.000), and LOTCA-G (r = 0.648, p < 0.000). MRMI was moderately correlated with MMSE (r = 0.545, p= 0.001), LOTCA-G (r = 0.514, p = 0.002), and postural

Table 3. Correlations among each variable in the faller group ($n = 34$).

	MBI	BBS	MRMI	MMSE	LOTCA-G	PSA_{EO}	PSA_{EC}
MBI		0.572**	0.514**	0.388**	0.211	−0.092	−0.081
BBS			0.790**	0.652**	0.648**	−0.205	−0.034
MRMI				0.545**	0.514**	−0.446**	−0.233
MMSE					0.787**	−0.147	0.031
LOTCA-G						−0.292	−0.036
$PSVM_{EO}$							0.761**
$PSVM_{EC}$							

MBI, Modified Barthel Index; BBS, Berg Balance Scale; MRMI, Modified Rivermead Mobility Index; LOTCA-G, Loewenstein Occupational Therapy Cognitive Assessment for Geriatrics; MMSE, Mini-Mental State Examination; $PSVM_{EO}$, Postural sway velocity moment with eye open; $PSVM_{EC}$, Postural sway velocity moment with eye close.

*$P < 0.05$, **$P < 0.01$, P values are quoted for correlation between variables in faller group.

Significant positively correlations were observed between ADL performance (MBI) and cognition [MMSE ($r = 0.388$, $p < 0.01$)], as well as dynamic balance [MRMI ($r = 0.514$, $p < 0.01$), BBS ($r = 0.572$, $p < 0.01$)] in the faller group.

Table 4. Correlations among each variable in the non-faller group ($n = 32$).

	MBI	BBS	MRMI	MMSE	LOTCA-G	PSA_{EO}	PSA_{EC}
MBI		0.292	0.496**	0.324	0.151	−0.033	−0.215
BBS			0.706**	0.210	0.300	−0.072	−0.210
MRMI				−0.086	0.111	−0.054	−0.271
MMSE					0.739**	−0.018	−0.118
LOTCA-G						−0.166	−0.314
$PSVM_{EO}$							0.779**
$PSVM_{EC}$							

MBI, Modified Barthel Index; BBS, Berg Balance Scale; MRMI, Modified Rivermead Mobility Index; LOTCA-G, Loewenstein Occupational Therapy Cognitive Assessment for Geriatrics; MMSE, Mini-Mental State Examination; $PSVM_{EO}$, Postural sway velocity moment with eye open; $PSVM_{EC}$, Postural sway velocity moment with eye close.

**$P < 0.01$, P values are quoted for correlation between variables in non-faller group.

Significant positively correlation was observed between ADL performance (MBI) and dynamic balance [MRMI ($r = 0.496$, $p < 0.01$)] in the non-faller group.

Table 5. Multivariate regression to identify factors related to ADL performance in the faller group ($n = 34$).

Dependent variable	Explanatory variable	Standardized coefficient (β)	F	R^2	t	P value*
MBI	BBS	0.572	15.551	0.327	3.943	< 0.000

MBI, Modified Barthel Index; BBS, Berg Balance Scale.

*P values are quoted for multivariate regression in faller group.

Using regression analysis, the R^2 was 0.327 ($P < 0.000$) and BBS could explain 32.7% variation in ADL performance of stroke patients with falls experience. This data indicates that impaired dynamic balance may be useful for monitoring reduction of ADL performance in post-stroke patients with fall experience.

sway velocity moment with eyes open ($r = -0.446$, $p = 0.008$). MMSE was moderately correlated with LOTCA-G ($r = 0.787$, $p < 0.000$). The postural sway velocity moment with the eyes open was moderately correlated with postural sway velocity moment with eyes closed ($r = 0.761$, $p < 0.000$; Table 3).

Correlations among each variable in the non-faller group

The correlations between variables in the non-faller group were as follows: MBI was moderately correlated with MRMI ($r = 0.496$, $p = 0.004$). BBS was moderately correlated with MRMI ($r = 0.706$, $p < 0.000$). MMSE was moderately correlated with LOTCA-G ($r = 0.739$, $p < 0.000$). The postural sway velocity moment with the eyes open was moderately correlated with postural sway velocity moment with eyes closed ($r = 0.779$, $p < 0.000$; Table 4).

Multivariate logistic regression in the faller group

In regression analysis, R^2 was 0.327 ($p < 0.000$); the BBS could explain 32.7% variation of ADL performance in the faller group (Table 5).

Discussion

Current study examined the impact of falling on cognitive and physical function in post-stroke patients. Falling is one of the most common complications of stroke, and stroke patients have a higher risk of falling than elderly (Jorgensen et al. 2002). Therefore, a number of studies have focused on fall prevention during inpatient stroke rehabilitation (Andersson et al. 2006; Czernuszenko and Czlonkowska 2009). Campbell and Matthews (2010) reported that the falls during inpatient stroke rehabilitation was considered as potential risk factors of impairment of balance and self-care. In particular, a fall leads to the fear of falling again and sustaining serious injuries such as a hip fracture and head injury (Dennis et al. 2002; Poole et al. 2002). According to a recent study targeting elderly, cognitive impairment can reduce the independence for performing basic ADL, and impairment of cognitive function is one of the risk factors associated with falls (Chen et al. 2011). However, in the clinic or researches for stroke rehabilitation, in general, impairment of physical function is more mainly evaluated than impairment of cognitive function. In this study, we found that cognitive function, dynamic balance, and ADL performance were significantly lower in the faller group, compared to non-faller group. In addition, static balance (the postural sway velocity moment with eyes open and eyes closed) was significantly higher in the faller group than in the non-faller group. This finding indicates that falling is associated with reduced physical function, as well as reduced cognitive function. Therefore, we suggest that cognitive function, as well as physical function should be considered in stroke rehabilitation for prevention of falls. In addition, the early assessment of cognitive function is crucial in the rehabilitation of stroke patients because cognitive impairment can limit functional gains during inpatient rehabilitation (Lamb et al. 2003). Thus, we suggest that rehabilitation for cognitive function should be included as part of a routine stroke rehabilitation program.

In this study, the correlation between cognitive and physical function (static and dynamic balance and ADL performance) in stroke patients with and without falls experience was also investigated. As a result, significant positively correlation was observed between MBI and MRMI in the non-faller group. However, in the faller group, significant positively correlations were observed between MBI and MMSE, BBS, as well as MRMI. In addition, regression analysis showed that dynamic balance (BBS) was a primary predictor for ADL performance in the faller group. R^2 was 0.327 ($p < 0.000$), and BBS could explain 32.7% variation in ADL performance.

Restoration of balance ability is a major component of stroke rehabilitation, because balance is considered important factor to maintain independence in various situations without falls (Kim and Park 2013). Many studies have identified balance ability as important risk factor for independent ADL in stroke patients (Tyson et al. 2007; Kim and Park 2013). Kim and Park (2013) reported that balance impairment leads to dependency in activities of daily living of stroke patients. Tyson et al. (2007) reported that balance ability affect performance in ADL of stroke patients. In addition, according to a previous study that examined the effect of cognitive impairment on functional limitation post-stroke, cognitive impairment caused by a stroke can have far-reaching consequences on ADL (Zinn et al. 2004). Through previous evidences and our findings, we assume that reduction of ADL is associated with decreased cognition and dynamic balance function in stroke patients. In particular, we suggest that enhancement of dynamic balance function could be effective for improving ADL in stroke patients with falls experience. This finding may be helpful for determining the intensity of ADL training in stroke patients.

This study has some limitations. First, because the data were collected from a single time point, it was hard to determine whether the changes in cognitive and physical function are attributable to the experience of falling or other factors such as the duration of hospitalization, rehabilitation, and medications. Therefore, additional studies on this issue will need to be conducted. Second, the changes in the level of awareness, use of medication, incontinence, and increased age (> 65 years) have previously been found to be associated with a risk of falls in stroke patients (Diccini et al. 2008).

Thus, future studies should consider these factors.

In conclusion, we found that stroke patients without fall experience performed better in the cognitive and physical function than stroke patients with fall experience. In addition, impaired dynamic balance may be useful for monitoring reduction of ADL performance in post-stroke patients with fall experience. We suggest that these findings may provide basic data for developing rehabilitation programs for improving the ADL performance in stroke patients.

Conflict of Interest

The authors declare no conflict of interest.

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