



Association between one-leg standing ability and postural control in persons with chronic stroke

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Objective: To investigate the association between one-leg standing ability and postural control for chronic hemiparetic stroke.

Design: Cross-sectional study.

Methods: Forty individuals who had a first diagnosis of stroke with hemiparesis before six months and over had participated in this study. To analyze the relationship between one-leg standing ability and postural control in the participants, six clinical measurement tools were used for assessment, including the Timed-Up-and-Go (TUG) test, Berg Balance Scale (BBS), Dynamic Gait Index (DGI), Fugl-Meyer Assessment (FMA), 5 times sit-to-stand (5TSTS) and one-leg standing (OLS).

Results: After analyzation, the OLS scores in the more-affected side showed significant positive correlations with BBS scores ($r=0.469, p<0.01$), DGI scores ($r=0.459, p<0.01$) and FMA scores ($r=0.425, p<0.01$). The OLS scores in the more-affected side showed significant negative correlations with TUG score ($r=-0.351, p<0.05$). The OLS score in the less-affected side showed significant positive correlations with BBS scores ($r=0.485, p<0.01$), DGI scores ($r=0.488, p<0.01$) and FMA score ($r=0.352, p<0.05$). The OLS scores in the less-affected side showed significant negative correlation with TUG scores ($r=-0.392, p<0.05$) and 5TSTS ($r=-0.430, p<0.01$). The OLS scores in the more-affected side showed significant positive correlations with the OLS scores in less-affected side ($r=0.712, p<0.01$).

Conclusions: The results of the study suggest that the OLS time may be moderately correlated with static and dynamic postural stabilities and motor recovery following stroke. This study also suggests that the OLS test is as a simple clinical tool for predicting postural control performance for individuals with chronic hemiparetic stroke.

Key Words: Postural balance, Standing position, Stroke

Introduction

Stroke involves various impairments in the neuromuscular system following a sudden case of cerebrovascular accidents, resulting in functional deficits in daily activities as well as social and recreational activities [1]. Initially, stroke survivors show direct neuromuscular deficits such as spasticity and abnormal reflexes. As the post-disease duration progresses and movement becomes more affected, the musculoskeletal system can develop secondary deficits such as muscular weakness and limited range of motion [2].

These movement problems can exhibit as deficits in the movements of the trunk the extremities due to missing components of movement control, atypical movement patterns that have gone awry from the normal coordinated movement, and unwanted movement compensations in order to produce functional strategies [3,4]. These impairments may impair the production of normal functional movements and may lead to a decrease in one's independent daily life activities such as walking on the even or uneven surfaces, moving around the home, picking up objects, and manipulating objects [1,3,5].

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One-leg Standing (OLS) is a necessary activity to perform dynamic standing balance and gait abilities in human life [6,7]. The OLS is a simple, but very promising exercise for improving balance for hemiparetic stroke survivors and it would help them prevent falls that can cause secondary serious injuries such as skin abrasion and bone fracture [6,7]. OLS requires stability and muscle activation of several muscles, such as the gluteus maximus, gluteus medius, tensor fascia lata, and multifidi in order to perform weight shifting onto the one-leg and to retain a steady posture, and rotate the ilium backward [8,9]. Several previous studies have reported that the OLS test is a simple clinical tool for predicting falls and postural control in clinical settings. Yoshimoto *et al.* [6] reported that the OLS time of the affected side may be considered as a moderately effective and simple assessment method for predicting post-discharge falls in the clinical setting. Flansbjerg *et al.* [7] also reported that OLS is strongly related to the Berg balance scale (BBS) and can be used as an independent test to measure upright postural control after a stroke. Sung and Leininger [9] also reported that the kinematic steadiness index during OLS could help to develop a practical tool to justify quantity and quality of postural balance outcome measures, which identify balance deficits and core spine rehabilitation strategies for recurrent low back pain.

This study aimed to investigate the strength of the association between one-leg standing ability and postural control for chronic hemiparetic stroke. This study assessed multiple individual tasks in which these scores were summed to create a composite score (BBS, dynamic gait index (DGI)), and also involved single tasks, such as the timed up-and-go test (TUG) and 5 times sit-to-stand (5TSTS). It was hypothesized that there would be a good relationship among the one-leg standing time, static and dynamic postural stabilities, motor recovery and sit-to-stand transfers in chronic hemiparetic stroke survivors.

Methods

This study was a cross-sectional, observational study that included outpatients from a local rehabilitation center to investigate the relationship between OLS ability and postural control for individuals with chronic hemiparetic stroke. The study was approved by the institutional review board of Baekseok University and all participants provided informed consent before the study (IRB No. BUIRB-201812-HR-013).

Participants

Forty stroke survivors who had received a diagnosis of stroke for the first time that was confirmed with cerebrovascular imaging before 6 months and over (24 males and 16 females, mean aged years, 59.32) were included in this study. The inclusion criteria was as follows: (1) a person who walked independently for 10 meter and over with or without any assistive devices on even surfaces; (2) a person with a modified Ashworth scale score of <2 of the muscles of the hip, knee or ankle area; (3) a person with a Montreal cognitive assessment-Korean version score of >23; (4) a person who was able to walk independently before the cerebrovascular accident; (5) a person who could follow the assessors' instructions and could understand the purpose of this study; and (6) a person who had no visuo-perceptual impairments. Subjects were excluded if they had a recurrent stroke, hypertension that was uncontrolled, a history of any other impairments of the neurological system aside from stroke, and any musculoskeletal impairments that could affect their postural control. Table 1 shows demographic and clinical characteristics of the participants in this study.

Experimental procedure

This study was a single-blinded research design, and was conducted by two assessors (Lee and Lee) with more than 5 years of evaluation experience except researchers. Six clinical measurement tools were used, which included the OLS, TUG, BBS, DGI, Fugl-Meyer assessment (FMA), and 5TSTS in order to investigate the relationship between OLS ability and postural control. With deciding the examination

Table 1. Common and clinical characteristics of participants in this study (N=40)

Variable	Value
Sex (male/female)	24/16
Age (y)	59.32 (13.00)
Etiology (infarction/hemorrhage)	19/21
Post-disease duration (mo)	37.12 (36.00)
Paretic side (Rt/Lt)	19/21
Brunnstrom's stage (3/4/5)	4/26/10
Timed up-and-go test (s)	23.46 (17.21)
Berg balance scale (score)	44.40 (9.63)
Dynamic gait index (score)	16.05 (5.71)
Fugl-Meyer assessment (score)	63.10 (27.71)
5 times sit-to-stand (s)	16.86 (6.02)

Values are presented as number only, number (%), or mean (SD).
Rt: right, Lt: left.

order by lot, the clinical test and measures were conducted on the participant. In all of the clinical measures, the assessor instructed the participant only one time and explained once more if he/she requested. The OLS, TUG and 5TSTS were measured three repetitions and the average value was used for data analysis. Other evaluations were measured and used for data analysis after calculating the total score.

Outcome measures

The OLS test a clinical tool used to examine steadiness in posture during the assumption of a static one-leg standing position by evaluating how long one is able to stand on one leg unsupported. No special equipment is needed except for a stop-watch, which is an inexpensive yet simple and time-efficient clinical measure. This test has an acceptable test-retest reliability and interrater reliability [10,11]. The TUG test evaluates the mobility of an individual who may have difficulty with postural control, sit-to-stand, and walking abilities. From a seated position, the participant stands up upon command, walks 3 meters, turns around, walks back to the chair and sits down. The normal range of the test is generally considered to be less than 10 seconds, and is 11 to 20 seconds in individuals with disabilities. If greater than 20 seconds, this may determine when assistance is required for outdoor walking performance. If the test is longer than 30 seconds, it is interpreted that there is a risk of falling. The test shows excellent test-retest reliability expressed by high intraclass correlation coefficients (range 0.431-0.994) [12,13].

The BBS is used to investigate the participant's ability to safely demonstrate static and dynamic postural stability except walking performance, and there are a total of 14 items. It is a five-point ordinal scale ranging from 0 (the lowest level of function) to 4 (the highest level of function). The test interprets a score of <45 as individuals who may be at greater risk of falling. Studies of various stroke populations have shown high intrarater and interrater reliability (intra-class correlation coefficient (ICC)=0.98) [14-16]. The DGI is used to evaluate postural control and gait abilities and complex gait tasks in a usual steady-state of walking with more challenging tasks. The DGI includes 8 items. Scores of 19 or less have been related to increase incidence of falls [17].

The FMA is a stroke-specific, performance-based impairment index developed by Fugl-Meyer and colleagues in 1975. The test involves the assessment of motor functioning, postural balance, sensation and joint functioning for hemiparetic stroke. It can evaluate the disease severity, motor re-

covery, and therapeutic effectiveness. It shows excellent test-retest reliability (ICC 0.81-0.97) [18,19].

Data analysis

All statistical analyses of the study were performed using the IBM SPSS Statistics for Windows, Version 25.0 (IBM Co., Armonk, NY, USA). Descriptive statistics were used to describe demographic and clinical characteristics in Table 1. To analyze the strength of the association between OLS ability and postural control, this study used the Pearson's correlation coefficient (r). To predict the value of OLS based on the other postural control variables, a multiple regression was performed. The significance level was set to $\alpha=0.05$.

Results

Table 2 shows the strength of the association between OLS ability and postural control. The OLS score for the more-affected side showed significantly positive correlations with BBS scores ($r=0.469$, $p<0.01$), DGI scores ($r=0.459$, $p<0.01$), and FMA scores ($r=0.425$, $p<0.01$). The OLS scores in the more-affected side showed significant negative correlations with TUG scores ($r=-0.351$, $p<0.05$). The OLS scores in the less-affected side showed significant positive correlations with BBS scores ($r=0.485$, $p<0.01$), DGI scores ($r=0.488$, $p<0.01$) and FMA scores ($r=0.352$, $p<0.05$). The OLS scores in the less-affected side showed significant negative correlations with TUG scores ($r=-0.392$, $p<0.05$) and 5TSTS ($r=-0.430$, $p<0.01$). The OLS scores for the more-affected side showed significant positive correlations with OLS scores for the less-affected side ($r=0.712$, $p<0.01$). TUG scores showed higher strength of the association between BBS and DGI, and showed moderate correlation between FMA and 5TSTS. The BBS had a significant strength in positive correlations with OLS time in both side and DGI score.

Table 3 shows the effects of OLS on postural control in participants. After the Durbin-Watson confirmation, it was judged that it was suitable for the multiple regression analysis model as it was close to 2 at 1.871 (TUG), 1.938 (BBS), 1.717 (DGI), 2.382 (FMA), and 1.994 (5TSTS). The BBS ($p=0.003$), DGI ($p=0.004$), FMA ($p=0.023$) and 5TSTS ($p=0.021$) were statistically significant in OLS scores for the more-affected side or OLS scores for the less-affected side. It was confirmed that there was no multicollinearity with tolerance and the variance inflation factor was 0.1 or more and less than 10 respectively. However, the OLS of the less-af-

Table 2. Relationship between OLS and postural control in participants

(N=40)

Variable	OLS in more-affected side	OLS in less-affected side	Timed up-and-go test	Berg balance scale	Dynamic gait index	Fugl-Meyer assessment	5 times sit-to-stand
OLS in more-affected side	1	0.712**	-0.351*	0.469**	0.459**	0.425**	-0.269
OLS in less-affected side	0.712**	1	-0.392*	0.485**	0.488**	0.352*	-0.430**
Timed up-and-go test	-0.351*	-0.392*	1	-0.856**	-0.827**	-0.528**	0.582**
Berg balance scale	0.469**	0.485**	-0.856**	1	0.870**	0.484**	-0.716**
Dynamic gait index	0.459**	0.488**	-0.827**	0.870**	1	0.629	-0.573**
Fugl-Meyer assessment	0.425**	0.352*	-0.528**	0.484**	0.629	1	-0.241
5 times sit-to-stand	-0.269	-0.430**	0.582**	-0.716**	-0.573**	-0.241	1

OLS: one-leg standing.

* $p < 0.05$, ** $p < 0.01$.**Table 3.** Effects of OLS on postural control in this study

(N=40)

Dependent variable	Independent variable	Unstandardized coefficient		Standard coefficient	t	p-value	Collinearity statistics		p-value	Durbin-Watson
		B	Std. Error	Beta			Tolerance	VIF		
Timed up-and-go test	OLS in more-affected side	-0.174	0.255	-0.146	8.694	0.500	0.493	2.030	0.360	1.871
	OLS in less-affected side	-0.249	0.185	-0.288	-1.347	0.186	0.493	2.030		
Berg balance scale	OLS in more-affected side	0.167	0.134	0.250	1.247	0.220	0.493	2.030	0.003	1.938
	OLS in less-affected side	0.148	0.097	0.307	1.529	0.135	0.493	2.030		
Dynamic gait index	OLS in more-affected side	0.089	0.080	0.226	1.125	0.268	0.493	2.030	0.004	1.717
	OLS in less-affected side	0.094	0.058	0.327	1.624	0.113	0.493	2.030		
Fugl-Meyer assessment	OLS in more-affected side	0.677	0.405	0.353	1.671	0.103	0.493	2.030	0.023	2.382
	OLS in less-affected side	0.139	0.294	0.100	0.473	0.639	0.493	2.030		
5 times sit-to-stand	OLS in more-affected side	0.031	0.088	0.076	0.358	0.722	0.493	2.030	0.021	1.994
	OLS in less-affected side	-0.146	0.064	-0.484	-2.291	0.028	0.493	2.030		

OLS: one-leg standing, Std: standard, VIF: variance inflation factor.

affected side was found to have a significant effect on the 5TSTS only, except for other postural control variables, including TUG, BBS, DGI, and FMA.

Discussion

OLS is a very simple test and exercise that can be easily ignored in the clinical setting. However, the OLS test is a variable that simply explains whether the person can walk independently and safely, and is a tool for identifying persons at high risk of requiring long-term care. The study was conducted to investigate the relationship between OLS ability and postural control for individuals with chronic hemiparetic stroke. The main results of the study were as follows: (1) OLS scores of the more-affected side was positively correlated with static and dynamic postural stabilities, walking abilities, motor recovery following stroke, and sit-to-standing transfers. (2) As a result of checking the affected part with the OLS as an independent variable, the OLS of the less-affected side was affected during sit-to-standing transfers only expect for postural stabilities, walking abilities and motor recovery following stroke.

Several studies have reported the relation between decreased OLS abilities and falls in the elderly population [6,20,21]. Michikawa *et al.* [20], had reported that the OLS test can be a tool for predicting frailty in community-dwelling elderly populations. They performed the review article collected from MEDLINE medical databases and selected 23 observational studies with individuals aged 65 years or older for analyses of mortality, falls, decreased activities of daily living (ADL), osteoporosis and so on. They suggested the findings are in consistent, although several studies have examined the relation between decreasing OLS times and falls. The review had also analyzed the relations between OLS times and ADL abilities. They reported that the OLS test can be used as a marker of a decline in ADL performance, including IADL [20]. According to one of more recent studies, a study by da Silva *et al.* [21] examined the time-limit of OLS and selected balance parameters obtained with a force platform in older and young adults and reported that the protocol can be used in the development of measurement tools for evaluating balance in older and young adults. Yoshimoto *et al.* [6] conducted a study to investigate for an accuracy of one-leg standing time in predicting post discharge falls in patients affected by stroke. They reported OLS time of the more-affected side may be considered as a moderately effective and simple assessment method for pre-

dicting post-discharge falls in the clinical setting.

The results of this study showed that OLS time in the more-affected side as well as in the less-affected side may be considered as to have moderate association strength with static and dynamic postural stabilities, motor recovery following cerebrovascular accident and a series of pre-determined walking tasks. Therefore, this study suggests that OLS test is a simple clinical tool for predicting postural control performance for chronic hemiparetic stroke survivors. In clinical settings, various and complex evaluations are made to accurately determine the stroke patients' condition. It can be difficult for both the assessor and the patient because many evaluations must be performed within a given time. Therefore, a simple and effective clinical measurement tool may be beneficial in clinical settings.

This study was conducted to evaluate the association between OLS and postural balance for chronic hemiparetic stroke survivors. This study was a cross-sectional, observational study design, not an experimental study. Therefore, future studies should consider whether OLS exercise can serve as a simple exercise for the improvement of postural balance and gait in people affected by stroke.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the authorship and/or publication of this article.

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