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Reliability of the Good Balance System® for Postural Sway Measurement in Poststroke Patients

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Abstract. [Purpose] The purpose of this study was to examine test-retest reliability of the Good Balance system® for measurement of postural sway in poststroke patients. [Subjects] Sixty chronic stroke patients (40 men and 20 women; age 63.08 years; stroke duration 16.45 months) participated in this study. [Methods] Postural sway was evaluated using a force platform system (Good Balance system, Metitur Oy, Jyvaskyla, Finland). Two examiners measured postural sway for all participants during two separate testing sessions. The second measurement was performed one week after the first measurement. Intraclass correlation coefficients [$ICC_{(2,1)}$] were used for estimation of reliability. [Results] The ICC (95% CI) for intra-examiner reliability was good to very good, ranging from 0.69 to 0.93 (0.53–0.96), and the ICC for inter-examiner reliability was good to very good, ranging from 0.85 to 0.98 (0.77–0.99). [Conclusion] The results of the current study indicated that the intra- and inter-examiner reliability of the Good Balance system® for measurement of postural sway was good to very good. Therefore, we suggest that measurement of postural sway using the Good Balance system® would be useful for clinical assessment in poststroke patients.

Key words: Postural sway, Reliability, Stroke

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INTRODUCTION

Poor postural control during ambulation or activities of daily living (ADL) is a common disability after stroke[1)]. Asymmetric weight bearing in a standing position has been shown to have a negative relationship with independence in performance of ADL[2)]. A previous study demonstrated that humans required three elements in order to control functional standing balance: maintenance of the standing position in static circumstances, maintenance of standing while experiencing internally produced perturbations associated with movements of their extremities, and maintenance of standing while experiencing externally produced perturbations[3)]. Postural control is essential for independence in performance of ambulation and ADL in poststroke patients; therefore, accurate evaluation of the postural control system is important[4)].

In general, traditional balance measures, such as the berg balance scale[5)], timed up and go test[6)], and functional reaching test[7)], are most commonly used as assessment tools for evaluation of postural control ability in stroke patients. However, these tools cannot be regarded as quantitative and objective methods of measurement[8)]. Recently, in the clinic or laboratory, computerized measurement and feedback systems have been used for evaluation of both static and dynamic balance control abilities[9, 10)]. Among the various types of equipment used for measurement of postural control, force platform technology can provide a method for quantifying an individual's postural control ability by measuring the center of pressure[11)]. In particular, the Good Balance system® consists of an equilateral triangular force platform connected to a computer through a three-channel amplifier with an analog to digital (A/D) converter. The following variables are calculated in the Good Balance system®: the extent of mediolateral (ML) movement of the center of pressure (COP) (X movement), the extent of anteroposterior (AP) movement of the COP (Y movement), and the mean values for all of the measurement points in relation to the midline of the platform (lateral displacement).

Despite use of the Good Balance system® in many studies as equipment for measurement of postural control ability[10, 12, 13)], there is no evidence regarding the reliability of the Good Balance system® in stroke patients. The reliability of measurement using the Good Balance system® need to be determined before it can be used as a potential predictor of functional performance. Thus, the purpose of this study was to examine the test-retest reliability of the Good Balance system® for measurement of postural sway in poststroke patients. We hypothesized that postural sway while maintaining postural control in a standing posture has ad-

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equate reliability for research and clinical use in stroke patients.

SUBJECTS AND METHODS

This single-group repeated-measures design involved a baseline measurement session and a follow-up session one week later. Subjects were recruited from patients admitted for rehabilitation following stroke. Subjects were included if they had (1) hemiparesis resulting from stroke for more than six months; (2) were able to understand and follow simple verbal instructions (Korean version of the Mini-Mental State Examination score > 21); (3) had no known musculoskeletal conditions that would affect the ability to stand safely; and (4) had no serious visual impairment or hearing disorder. Potential subjects were excluded if they had cardiovascular or other conditions affecting their balance and were unable to provide informed consent. All subjects underwent conventional rehabilitation programs consisting of physical and occupational therapy during the duration of hospitalization. General characteristics of the subjects were obtained from their medical records. Six of the 66 potential subjects were excluded because they met the exclusion criteria. Finally, 60 subjects were included in this study. We explained the objective and requirements of our study to all participants, and they voluntarily signed informed consent forms. Ethical approval for the study was granted by the Sahmyook University institutional review board.

The Good Balance system® (Good Balance system, Metitur Oy, Jyvaskyla, Finland) was used for measurement of postural sway velocity and velocity moment of subjects in the standing posture. On the basis of these coordinate values for x and y, the following parameters were calculated: (1) mean speed of the movement of the COP in the AP direction (mm/s); (2) mean speed of the movement of the COP in the ML direction (mm/s), and (3) mean velocity moment (mm^2/s). Postural sway velocity moment is defined as the average horizontal area covered by movement of the center (AP and ML direction) of force per second. The force platform, which was an equilateral triangle (800 mm), was connected to a three-channel DC amplifier. Signals from the amplifier were converted into digital form using a 12-byte converter (sampling frequency=50 Hz) and stored on the hard disk of a personal computer.

To measure postural sway, a subject stood on the force plate with their legs spread at shoulder width and then looked at a number on a monitor for 30 seconds. In order to measure postural sway, the subjects were asked to stand quietly in a comfortable upright position on the force plate while looking straight ahead. All tests were performed with shoes removed. According to the user manual, a distance of between 1 to 3 m is suitable for accurate measurements. In our study, the distance between the subject and the monitor was set 1.5 m. The following instruction was communicated to the subjects in order to ask them to move their bodies as little as possible: "Please try your best to stand without swaying."

Two physical therapists participated as examiners in the reliability analysis based on previous evidence[14]. Examiners acquired data from all participants during two separate testing sessions (sessions one and two). Three repeats of each measurement sessions were performed, and the average was used in each session. A rest period (three minutes) was provided between measurements in order to prevent fatigue. After the first measurement was performed, the second measurement was performed one week later. Testing sessions were held at the same time of day for each participant.

Intraclass correlation coefficients [$ICC_{(2,1)}$] were used to determine the test-retest reliability for postural sway between the two measurement sessions. ICC values less than or equal to 0.20 were considered poor; 0.21 to 0.40, 0.41 to 0.60, 0.61 to 0.80, and 0.81 to 1.00 were considered to be fair, moderate, good, and very good values, respectively[15]. The paired t-test was performed in order to test for any systematic differences between sessions. Results were considered significant at $p<0.05$, and statistical analyses were performed using SPSS ver. 12.0 (SPSS for Windows; SPSS Inc, Chicago, IL, USA).

RESULTS

A summary of the general characteristics of the subjects who completed the measurements successfully is shown in Table 1. A summary of the results for intra-examiner reliability of postural sway for the two sessions is shown for the two examiners in Table 2. The ICC (95% CI) for all measures was good to very good, ranging from 0.69 to 0.93 (0.53–0.96). A summary of the results for inter-examiner reliability of postural sway for the two sessions between examiners is shown in Table 3. The ICC (95% CI) was good to very good for all measures, ranging from 0.85 to 0.98 (0.77–0.99).

DISCUSSION

This study was conducted in order to determine the suitability of the Good Balance system® for measurement of postural sway in poststroke patients. Our main results demonstrate good to very good inter- and intra-reliability of the Good Balance system® for estimating a stroke patient's postural sway measurement.

Postural sway measurements using a force plate record vertical strength and can be used to explain postural control ability using parameters such as postural sway velocity and velocity moment[16]. The amount of postural sway is usually divided into the anteroposterior direction and the mediolateral direction[17]. In general, postural sway is known to increase with age, and the frequency of falls increases as sway increases[18]. In addition, postural sway is 1–1.5 times higher in stroke patients than in elderly people[19]. The ability to maintain body balance against externally produced perturbations is achieved by the postural control system. Thus, impairment in this system could lead to increased postural sway as observed in stroke patients[20]. In other words, accurate evaluation for postural sway in stroke patients is important for successful rehabilitation and return to the home and community.

Many previous studies targeting elderly people have re-

Table 1. General characteristics of the subjects

Variables	Male (n=40)	Female (n=20)	Overall (n=60)
Paretic side Left/Right (%)	11/29 (27.5/72.5)	5/15 (25/75)	16/44 (26.2/72.1)
Etiology Infarction/Hemorrhage (%)	24/16 (60/40)	13/7 (65/35)	37/23 (60.7/37.7)
Age (years)	63.1±6.2	63.0±6.7	63.1±6.3
Height (cm)	165.3±6.8	157.4±4.2	162.7±7.1
Weight (kg)	62.3±8.0	56.3±5.6	60.3±7.8
Onset duration (months)	16.6±3.0	16.3±2.4	16.4±2.8
BBS (scores)	38.8±4.8	39.3±3.5	38.9±4.4
TUG (sec)	24.1±3.8	24.1±3.7	24.1±3.7
MMSE-K (scores)	25.7±2.8	26.1±2.8	25.9±2.8

Values are expressed as n (%) or as the mean±SD.
BBS, Berg balance scale; TUG, Timed up and go test; MMSE-K, mini mental state examination-Korean version

Table 2. Intra-examiner reliability of postural sway (n=60)

	Variables		Session 1	Session 2	ICC	95% CI
E1	Velocity (mm/s)	AP	8.5±4.4	8.0±4.6	0.87	0.79–0.92
		ML	13.1±4.5	12.7±4.9	0.69	0.53–0.80
	Velocity moment (mm^2)		36.8±21.0	37.1±21.0	0.87	0.79–0.92
E2	Velocity (mm/s)	AP	8.8±4.1	8.4±4.1	0.93	0.89–0.96
		ML	13.3±4.1	13.0±4.5	0.78	0.66–0.86
	Velocity moment (mm^2)		37.5±20.2	36.5±19.2	0.93	0.89–0.95

Values are expressed as the mean±SD.
E, examiner; AP, anteroposterior; ML, mediolateral; ICC, intraclass correlation coefficient; 95% CI, 95% confidence interval

Table 3. Inter-examiner reliability of postural sway (n=60)

Variables		1st test		2nd test	
		ICC	95% CI	ICC	95% CI
Velocity (mm/s)	AP	0.97	0.95–0.98	0.92	0.88–0.95
	ML	0.92	0.87–0.95	0.85	0.77–0.91
Velocity moment (mm^2)		0.96	0.94–0.98	0.96	0.93–0.97

AP, anteroposterior; ML, mediolateral; ICC, intraclass correlation coefficient; 95% CI, 95% confidence interval

ported good reliability of postural sway measured using a force platform. For example, Lafond et al.[21] assessed the intra-session reliability of COP measurement of postural steadiness in elderly. They reported that mean velocity was the most reliable measure of COP. In addition, Benvenuti et al.[22] found good reliability (ICC=0.74) based on two consecutive trials for COP mean velocity. However, the reliability of postural sway outcome in stroke patients has been addressed in only a few studies, and the results were not consistent. Liston et al.[4] investigated reliability of measures obtained from 20 stroke patients using the Balance Master and reported its reliability for both movement path (ICC=0.84) and time (ICC=0.88). In contrast, Helbostad et al.[23] reported that two repeated measures gave adequate repeatability for elderly people but not for stroke patients when they were tested with their eyes open. Because these findings were obtained from relatively small sample size (12 and 23 stroke patients), the results of these studies are not unequivocal. Therefore, in the current study, we investigated the reliability in a larger sample size (60 stroke patients), and the results demonstrated good to very good intra- and inter-examiner reliability of the Good Balance system® for measurement of postural sway. Therefore, we suggest that measurement of postural sway using the Good Balance system® would be useful for clinical assessment in poststroke patients.

The current study showed that the measurements of postural sway obtained from the Good Balance system® were reliable in the intra- and inter-reliability analysis, but there are some limitations. In the current study, we determined that the Good Balance system® was reliable equipment for measurement of postural sway. However, the findings of previous studies targeting stroke patients were not consistent; therefore, there is still the potential for controversy. Thus, we suggest that further study on the reliability of postural sway measurements using a force plate targeting stroke patients is needed. Another limitation of the current study is the small number of measurements for each session (only three measurements). Conduct of a larger number of trials might contribute to the reliability of postural sway measurement. Thus, conduct of additional studies on this issue is required.

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