The Journal of Physical Therapy Science

Original Article

Correlation between accelerometry and clinical balance testing in stroke

Jaeyeop Chung, PhD, OT[1], Sungshin Kim, PhD, PT[2], Yeongae Yang, PhD[3]*

[1] Department of Occupational Therapy, Kyongbuk Science College, Republic of Korea
[2] Department of Design and Human Engineering, Ulsan National Institute of Science and Technology, Republic of Korea
[3] Department of Occupational Therapy, College of Biomedical Sciences and Engineering, Inje University and Institute of Elderly Life Redesign: 607 Obang-dong, Gimhae-si, Gyeongsangnam-do 621-749, Republic of Korea

Abstract. [Purpose] The purpose of this study was to determine the correlation between the Berg Balance Scale (BBS) and acceleration of postural sway in the Clinical Test of Sensory Interaction and Balance (CTSIB) by using a triaxial accelerometer for quantitative assessment. [Subjects and Methods] Twenty-seven stroke patients participated in this study. Balance ability was evaluated with the BBS, and postural sway was evaluated with a triaxial accelerometer. The data were then analyzed for frequency and correlation by using statistical software (SPSS 18.0). [Result] Acceleration in left-right and forward-backward directions in all conditions of the CTSIB assessment showed a significant correlation with BBS assessment. Acceleration in Signal Vector Magnitude values in condition 3 of the CTSIB assessment showed a significant correlation with BBS assessment. [Conclusion] This study revealed that postural sway represented balance ability as acceleration in the quantitative measurement of kinematic analysis. This finding suggests that the triaxial accelerometer could be used as a measurement tool in clinical conditions.
Key words: Berg Balance Scale, Clinical Test of Sensory Interaction, Triaxial accelerometer

INTRODUCTION

Balance is a generic term describing the dynamics of body posture involved in preventing a fall. Balance disorders in stroke patients have a negative effect on activities of daily living and functional independence levels[1, 2]. Setting rehabilitation objectives as well as assessing progress is dependent on the ability to identify and quantify balance impairments and functional abilities[3–5]. The ideal assessment method should provide objective and quantitative measurements that can be easily translated into simple and useful information. Advances in computerized technology have made objective assessments of balance increasingly practicable in clinical environments[6].

The Berg Balance Scale (BBS) is a widely used standardized method for the assessment of balance ability[7, 8]. A version of this scale has also been developed for use in Korea[9]. In the BBS assessment, items such as transfer sitting, rotation, and stretching are used to determine treatment and to recommend auxiliary tools for independent daily living, as well as to reduce the risk of falling in those with changes in their sensory system[4]. The Clinical Test of Sensory Interaction and Balance (CTSIB) was first introduced by Shumway-Cook and Horak as a clinical adaptation of the Sensory Organization Test. The CTSIB is a timed test that was developed for systematic testing of the influence of visual, vestibular, and somatosensory input on standing balance[10]. This test is inexpensive, requires minimal equipment, and is currently in use by clinicians. Conditions 1, 2, and 3 involve standing on the floor with eyes open, eyes closed, and wearing a visual conflict dome. Conditions 4, 5, and 6 involve standing on foam and repeating the visual conditions described for conditions 1 through 3. For each condition, the

Table 1. Clinical characteristics of subjects (N=27)

		n	%	Mean ± SD
Gender	Male	21	77.8	
	Female	6	22.2	
Age (yrs)	≤29	3	11.1	
	30–39	3	11.1	
	40–49	7	25.9	50.2 ± 16.9
	50–59	7	25.9	
	≥60	7	25.9	
Hemiparetic side	Rt.	14	51.9	
	Lt.	11	40.7	
	Both	2	7.4	
Onset (mon)	≤3	5	18.5	
	4–6	3	11.1	
	7–12	9	33.3	10.4 ± 6.9
	13–24	10	37.0	

Table 2. Balance abilities of the subjects (N=27)

			Mean	SD	Min	Max
BBS			39.67	12.67	10	55
Postural Sway	RMS (g)	X axis	0.0266	0.0133	0.0035	0.0580
		Y axis	0.0129	0.0092	0.0041	0.0741
		Z axis	0.0047	0.0974	0.0186	0.0120
	SVM (g)		1.1040	0.1340	0.9984	1.8733

BBS: Berg Balance Scale; RMS: Root Mean Square; SVM: Signal Vector Magnitude

length of time for which the subject can maintain the standing position and the amount of body sway are assessed.

The accelerometer has been widely used to measure balance in many studies[11–14]. Even though an accelerometer is used to measure speed variation of a vehicle, many studies of various human activities, such as path of movement, range of activities, and postural changes, use the acceleration scale. Since the 1990s, many studies have been conducted on human activities or performance in the field of medicine, using miniaturized sensors. Studies on falling or monitoring of patient activities using an acceleration sensor are ongoing[15].

This study aimed to determine the correlation between the BBS and the acceleration of postural sway in the CTSIB assessment by using a triaxial accelerometer for quantitative balance measurements.

SUBJECTS AND METHODS

This study evaluated patients in a rehabilitation hospital in Gyeonggi-do who had a stroke within the prior 2 years. The study complied with the ethical standards of the Helsinki Declaration. Written informed consent was obtained from each subject. The assessment tools for balance and postural sway were the BBS and CTSIB. We replaced the visual conflict dome with opaque vinyl goggles for practicality and usability in the hospital. A wireless triaxial accelerometer was used Trigno™ Wireless Electromyography System (Delsys Inc., Boston, MA, USA). The EMGworks program (Delsys, Inc., Boston, MA, USA) was used to convert the values of acceleration to Root Mean Square values (RMS), in order to remove the mean and to compare different axes and Signal Vector Magnitude (SVM). The collected data were analyzed by using statistical package for social science (SPSS) 18.0 (SPSS Inc., Chicago, IL, USA) to obtain frequency and correlation coefficients.

$$SVM = \sqrt{X^2 + Y^2 + Z^2}$$

Table 3. Correlation analysis between BBS and acceleration of postural sway in CTSIB (N=27)

		Condition1	Condition2	Condition3	Condition4	Condition5	Condition6
	Up-Down	−0.194	−0.253	0.010	−0.107	−0.126	−0.151
RMS	Left-Right	−0.507**	−0.595**	−0.513**	−0.682***	−0.670***	−0.650***
	Forward-Backward	−0.402*	−0.653***	−0.576**	−0.390*	−0.437*	−0.576**
SVM		−0.214	−0.340	−0.385*	0.049	−0.017	0.013

BBS: Berg Balance Scale; CTSIB: Clinical Test of Sensory Interaction and Balance; RMS: Root Mean Square; SVM: Signal Vector Magnitude.
*$p<0.05$, **$p<0.01$, ***$p<0.001$

RESULTS

General characteristics of the 27 subjects are shown in Table 1. The balance ability of the subjects is shown in Table 2. The correlation between the BBS assessment and the 6 conditions of the CTSIB assessment was examined. According to the analysis of RMS values for acceleration in the CTSIB assessment and total BBS score, left-right and forward-backward direction measurements in all conditions showed a significant correlation ($p<0.05$). Moreover, according to the analysis of SVM values for acceleration in the CTSIB assessment and the total BBS score, postural sway measured in condition 3 showed a significant correlation ($p<0.05$) (Table 3).

DISCUSSION

Wearable motion sensors developed for robotics, aerospace, and biomedical measurements have recently been used to measure balance control[16, 17]. Sensors with wireless data transfer have the potential to overcome the major drawbacks of cost, size, and the location limitation of computerized testing, and may enable the objective measurement of postural sway and movements during task performance.

The purpose of this study was to determine the correlation between the BBS and the acceleration of postural sway in CTSIB assessment by using a triaxial accelerometer. The present study found that postural sway measured in condition 3 showed an inverse correlation ($p<0.05$) between SVM values for acceleration in CTSIB assessment and the total BBS score. According to a study by O'Sullivan et al., the accelerometer in condition 4 was inversely correlated with the BBS[14].

Analysis of balance utilizes either clinical scales or instrumentation. The advantage of the former is mainly related to the need to individually assess balance in each patient with a stroke, irrespective of the severity of impairment. The advantage of the latter is mainly related to the fact that in some conditions, the use of new technology is helpful for understanding diseases[1]. Current clinical assessment of balance is complicated by the lack of reliable, objective, inexpensive, simple, and time-efficient tests. Clinical testing can be partly subjective, but there are benefits to be gained from the examination of postural control and balance in a more quantitative manner. Many tests described in the literature are impractical for a clinical setting, as they may require sophisticated equipment or are time-consuming and expensive to administer[18]. Most researchers using quantitative measurements to assess static postural sway have used a force platform[19].

This study conducted a kinematic analysis of balance by using a triaxial accelerometer as a quantitative measurement instrument. The usefulness of balance assessment by the accelerometer was demonstrated through a correlation analysis between acceleration of postural sway in CTSIB assessment and the BBS. Limitations and comments are as follows. Movement was quantitatively presented on each axis by using a triaxial accelerometer, but movement by the human body does not occur along one axis alone. Moreover, we analyzed the correlation between BBS assessment and accelerometry, but future research using another objective assessment instrument should be conducted to compare and analyze not only kinetic but also kinematic data.

ACKNOWLEDGEMENT

REFERENCES

1) Benaim C, Pérennou DA, Villy J, et al.: Validation of a standardized assessment of postural control in stroke patients: the Postural Assessment Scale for Stroke Patients (PASS). Stroke, 1999, 30: 1862–1868. [Medline] [CrossRef]

2) Liaw LJ, Hsieh CL, Lo SK, et al.: The relative and absolute reliability of two balance performance measures in chronic stroke patients. Disabil Rehabil, 2008, 30: 656–661. [Medline] [CrossRef]

3) Cohen H, Miller LV, Kane-Wineland M, et al.: Vestibular rehabilitation with graded occupations. Am J Occup Ther, 1995, 49: 362–367. [Medline] [CrossRef]

4) Horak FB: Clinical assessment of balance disorders. Gait Posture, 1997, 6: 76–84. [CrossRef]

5) Leonard E: Balance tests and balance responses: performance changes following a CVA: a review of the literature. Physiother Can, 1990, 42: 68–72.

6) Mancini M, Horak FB: The relevance of clinical balance assessment tools to differentiate balance deficits. Eur J Phys Rehabil Med, 2010, 46: 239–248. [Medline]

7) Berg K, Wood-Dauphinee S, Williams JI: The Balance Scale: reliability assessment with elderly residents and patients with an acute stroke. Scand J Rehabil Med, 1995, 27: 27–36. [Medline]

8) Berg KO, Maki BE, Williams JI, et al.: Clinical and laboratory measures of postural balance in an elderly population. Arch Phys Med Rehabil, 1992, 73: 1073–1080. [Medline]

9) Jung HY, Park JH, Shim JJ, et al.: Reliability test of Korean version of berg balance scale. J Korean Acad Rehabil Med, 2006, 30: 611–618.

10) Shumway-Cook A, Horak FB: Assessing the influence of sensory interaction of balance. Suggestion from the field. Phys Ther, 1986, 66: 1548–1550. [Medline]

11) Kamen G, Patten C, Du CD, et al.: An accelerometry-based system for the assessment of balance and postural sway. Gerontology, 1998, 44: 40–45. [Medline] [CrossRef]

12) Mayagoitia RE, Lötters JC, Veltink PH, et al.: Standing balance evaluation using a triaxial accelerometer. Gait Posture, 2002, 16: 55–59. [Medline] [CrossRef]

13) O'Sullivan M, Blake C, Cunningham C, et al.: Correlation of accelerometry with clinical balance tests in older fallers and non-fallers. Age Ageing, 2009, 38: 308–313. [Medline] [CrossRef]

14) Whitney SL, Roche JL, Marchetti GF, et al.: A comparison of accelerometry and center of pressure measures during computerized dynamic posturography: a measure of balance. Gait Posture, 2011, 33: 594–599. [Medline] [CrossRef]

15) Bonato P: Advances in wearable technology and applications in physical medicine and rehabilitation. J Neuroeng Rehabil, 2005, 2: 2. [Medline] [CrossRef]

16) Mathie MJ, Celler BG, Lovell NH, et al.: Classification of basic daily movements using a triaxial accelerometer. Med Biol Eng Comput, 2004, 42: 679–687. [Medline] [CrossRef]

17) Chiari L, Dozza M, Cappello A, et al.: Audio-biofeedback for balance improvement: an accelerometry-based system. IEEE Trans Biomed Eng, 2005, 52: 2108–2111. [Medline] [CrossRef]

18) Stevenson TJ, Garland SJ: Standing balance during internally produced perturbations in subjects with hemiplegia: validation of the balance scale. Arch Phys Med Rehabil, 1996, 77: 656–662. [Medline] [CrossRef]

19) Laughton CA, Slavin M, Katdare K, et al.: Aging, muscle activity, and balance control: physiologic changes associated with balance impairment. Gait Posture, 2003, 18: 101–108. [Medline] [CrossRef]