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 (This article was submitted Feb. 26, 2016, and was accepted May 7, 2016)

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 levels1, 2). Setting rehabilitation objectives as well as assessing progress is dependent on the ability to identify and quantify balance impairments and functional abilities3–5). 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 environments6). The Berg Balance Scale (BBS) is a widely used standardized method for the assessment of balance ability7, 8). A version of this scale has also been developed for use in Korea9). 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 system9). 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 balance10). 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
The accelerometer has been widely used to measure balance in many studies\textsuperscript{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\textsuperscript{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.

\[
\text{SVM} = \sqrt{X^2 + Y^2 + Z^2}
\]
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 control16, 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 BBS14).

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 diseases1. 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 administer18). Most researchers using quantitative measurements to assess static postural sway have used a force platform19).

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

This study was extracted from the dissertation for a doctoral degree.

REFERENCES


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

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

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


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2263