Objectives. Asymmetrical posture during static stance has been identified as a common problem in persons with hemiplegia. This study examined the effect of an activity-based therapy regimen on symmetric weight bearing and midline position of center of gravity (COG) in three adult subjects with hemiplegia.

Method. An ABAB single-subject design was used. The intervention program, including sanding in front of a standing table and play a bean bag game, was introduced for 30 min each day during each intervention phase. Quantitative measurements of the weight distribution and the midline position of COG were taken with the Balance Master System (version 2.20).

Results. Visual inspection and statistical analysis of the data revealed a significant improvement in symmetric weight distribution and midline position of COG. The study suggests that this program may be a promising alternative to a variety of postural rehabilitation programs for persons with hemiplegia.

Conclusion. Insecurity caused by poor stabilization and abnormal reactions to body weight bearing in an antigravity position might contribute to asymmetric postures. Results of this study suggest that an activity-oriented program can be effective in helping the persons with hemiplegia achieve symmetric stances.

Asymmetric weight distribution in the lower extremities and deviation of the center of gravity (COG) from body midline have been identified as common problems for persons with hemiplegia during static stance (Arcan, Brull, Najenson, & Solzi, 1977; Badke & Duncan, 1983; Dettmann, Linder, & Sepic, 1987; Milczarek, Kirby, Harrison, & MacLeod, 1993). Lack of symmetry in postural control was found to correlate significantly with measures of walking performance in persons with hemiplegia (Bogardh & Richards, 1981; Dettmann et al., 1987; Ring & Mizrahi, 1991; Wall & Turnbull, 1986). Asymmetrical posture during static stance has also been suggested to be a major cause of falls (Di Fabio & Badke, 1990; Hochermen, Dickstein, & Pillar, 1984; Twitchell, 1951). Dettmann et al. (1987) demonstrated an important correlation between measurements of upright stability and functional assessment scores on the Barthel Index (Mahoney & Barthel, 1965) in subjects with hemiplegia. Badke and Duncan (1983) found that patients with hemiplegia who have low motor performance scores of the lower extremity on the Fugl-Meyer assessment exhibited greater abnormalities in postural adjustment (Fugl-Meyer, Jaasko, Leyman, Olsson, & Steglin, 1975).

Postural stabilization has been established as essential during preparatory and ongoing voluntary movements (Belenkii, Gurfinkel, & Pal'tsev, 1967; Cordo & Nashner, 1982; Gurfinkel, Lipshits, Mori, & Popov, 1981; Horák, Esselman, Anderson, & Lynch, 1984; Lee, 1980).
Lee (1989) further suggested that free limb performance in activities of daily living could be limited by abnormal postural control. Accordingly, a symmetrical standing posture should be the foundation for optimal functions in locomotor performance and activities of daily living. Therefore, one functional goal in rehabilitating persons with hemiplegia should be set to improve symmetrical characteristics of postural control. Numerous studies have been published on the improvement of postural control during static standing. Use of loading exercises emphasizing weight transfer and weight bearing on the affected limb have been shown to be effective in reducing the asymmetrical standing posture (Bohannon & Larkin, 1985; Dickstein, Nissan, Pillar, & Scheer, 1984; Lane, 1978; Rogers, Hedman, & Pai, 1995). Biofeedback techniques to provide patients with auditory or visual information regarding limb loading or the position of COG during postural exercises have been investigated and reported to be successful in reestablishing stance symmetry (Hamman, Mekjavic, Mallinson, & Longridge, 1992; Seeber & Caudrey, 1981; Shumway-Cook, Anson, & Haller, 1988; Wannstedt & Herman, 1978; Winston, Gardner, McNeal, Barto, & Nicholson, 1989).

An activity-oriented intervention for postural control has been implemented in the rehabilitation of patients with hemiplegia for many years in our facility. The intervention used in this study is different from other approaches that only involve the mechanical loading of weight on the patients’ affected sides. Our strategy emphasizes the use of purposeful activities to direct motor relearning, process and organize all incoming information, and coordinate the whole body to achieve a better learning effect on postural control (Wu, 1987, 1990). The purpose of this study was to evaluate the effects of this program in improving symmetrical weight bearing and midline position of COG in three subjects with hemiplegia.

Method

Subjects

Three patients hospitalized for cerebrovascular accident (CVA) participated in this study. All had hemiplegia but were able to stand independently with no assistive devices at initial testing. The subjects had no evident language, cognition, or sensory deficits. Their gender, age, affected side, and duration since CVA are shown in Table 1.

Research Design

An ABAB (withdrawal–reinstatement) single-subject design was used to provide evidence of intervention effects (Kazdin, 1982; Ottenbacher, 1986). Baseline measurements of weight distribution and mean position of COG were taken in the first A phase, and intervention was implemented during the first B phase, withdrawn during the second A phase, and reinstated during the second B phase. Each phase lasted 7 days. Measurements were conducted each day, for a total of 28 sessions. During each A phase, measurements were taken each day. During each B phase, measurements were taken the day after treatment.

Measurement

The Balance Master System (version 2.20)\(^1\) was used to measure the midline position of COG and weight bearing distribution. During each measurement session, the subject was positioned on the Balance Master forceplate, with the recommended foot placement, and asked to stand as symmetrically as possible, keeping his or her feet still and arms relaxed at both sides. The weight-bearing parameter was selected through Balance Master’s Therapy Menu (F4, View Weight Distribution software) (NeuroCom International Inc., 1989). Three readings were taken for each measurement of weight distribution, and the average was used for data analysis.

The COG position was selected from Balance Master’s Standard Assessment Menu (F1, Align–No Target, Eyes Open). Data were collected for 20 sec and expressed as a percentage of the theoretical limits of stability in the mediolateral direction (NeuroCom International Inc., 1989).

Intervention Program

The intervention program consisted of two activities: sanding in front of a standing table and participating in a bean bag game. The intervention program lasted for 30 min each day. Subjects only received this intervention program in their occupational therapy sessions. These two activities were selected because (a) they are simple to perform, (b) the subjects were familiar with them, and (c) they are intrinsically performed in an upright (antigravity) position. We believe that any activity with the above qualities is a suitable choice for postural control training in patients with hemiplegia. During the course of this study, the subjects still received physical therapy every day.

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\(^1\)NeuroCom International Inc., 9570 SE Lawrie Road, Clackamas, Oregon 97015-9611.

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### Table 1 

**Subject Characteristics**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Gender</th>
<th>Age (Years)</th>
<th>Affected Side</th>
<th>Duration Since CVA (Weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Male</td>
<td>50</td>
<td>Right</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Female</td>
<td>66</td>
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<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Male</td>
<td>62</td>
<td>Left</td>
<td>5</td>
</tr>
</tbody>
</table>

*Note: CVA = cerebrovascular accident*
However, during both A phases, no further occupational therapy was provided.

**Procedure**

*Standing in Front of Standing Table*

The subjects stood in front of the standing table in an erect position with a separator between the heels. The affected elbow was supported by suspension, and the affected hand was fixed onto the bar of the sander. Subjects with an asymmetrical posture were positioned in normal alignment with a strap. The subjects were asked to push the sander forward and pull it backward bilaterally and slowly while keeping the trunk of their bodies firmly fixed (i.e., no backward movement of the trunk during the pulling action). We deliberately asked the subjects to perform this activity in this posture to train trunk stability (fixation of the trunk) without excessive body sways or any tendency of falling backward. The subjects were asked to complete 3 rounds of 10 repetitions of the sanding action. Resistive weight was applied progressively with each round.

**Bean Bag Game**

This activity was carried out in a standing position. The therapist stood next to the subjects' affected side and assisted them in maintaining a normal posture. The subjects were asked to use their unaffected hand to pick up a bean bag placed in front of them and throw it at a target. The bean bag was placed in several different locations in relation to the subject according to a hierarchically ordered sequence: Grade 1, on the ground in an upwardly sloping direction about 60 cm to 75 cm from the subject's unaffected foot; Grade 2, on the ground in front of the subject's unaffected foot; Grade 3, on the ground in front of the subject's midline; and Grade 4, on the ground in front of the affected foot. The distance between the bean bag and the subject's big toe was 45 cm to 60 cm for Grades 2 through 4, depending on the subject's condition. The distance between the target and the subject was 90 cm to 450 cm, depending on the subject's condition. Bean bag placement started with Grade 1 and progressed one grade at a time as the subject became comfortable reaching for the bean bag. The subjects were asked to complete 3 rounds of 10 repetitions of the picking up and throwing actions.

**Data Analysis**

Visual analysis of data is the standard method used for single-subject design studies (Kazdin, 1982; Ottenbacher, 1986; Wolery & Harris, 1982). The measurements collected from each session across all four phases (ABAB) were plotted on a simple line graph for visual inspection. Data were tested for serial dependency of the separate phases by computing the autocorrelation coefficient. A celeration line was drawn to aid in the visual analysis of changes in the subjects' performance. Bloom’s probability table was used to determine whether the number of data points above or below the projected celeration line in the intervention phases was significant (Ottenbacher, 1986).

**Results**

The measurements collected for each variable for all three subjects and the means for each phase are shown in Figures 1 and 2. The autocorrelation coefficients computed across the seven measurements within each phase are presented in Table 2. When Bartlett’s test was applied to determine whether the autocorrelation for each phase was statistically significant, the coefficients were less than $2/\sqrt{n} = 2/\sqrt{7} = .756$ ($n$ = number of baseline observations). The lack of a significant coefficient indicates that the data were not serially dependent in any phase. This finding suggested that visual inspection and the celeration line approach would be appropriate for the data analysis.

The celeration line for the baseline and treatment-withdrawal (A) phases was extended into the intervention (B) phases, and the proportion of the data points above (or below) this line was evaluated. For all three subjects, the data points during the intervention phases were found to be completely above the projected celeration line for the weight distribution variable (see Figure 1) and completely below the projected celeration line for the midline deviation from COG variable (see Figure 2). This finding suggests that a change in the subjects’ performance during the intervention phases was significant when Bloom’s probability table was used (Ottenbacher, 1986). From the plots in Figure 1, it can be observed that most of the data points in the B phases fell above the celeration line, representing the subjects’ tendency to put more weight over their affected legs. In Figure 2, most of the data points in the B phases fell below the celeration line, implying that the subjects displayed fewer COG sways during the intervention phases. Moreover, a uniform positive trend (i.e., toward 50% of weight distribution) could also be observed across both B phases (see Figure 1), representing a continuous progression in weight bearing over the affected leg during the interven-

<table>
<thead>
<tr>
<th>Subj.</th>
<th>Weight Bearing</th>
<th>Position of Center of Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>1</td>
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<td>.672</td>
</tr>
<tr>
<td>2</td>
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<td>.535</td>
</tr>
<tr>
<td>3</td>
<td>.499</td>
<td>.582</td>
</tr>
</tbody>
</table>
**Figure 1.** Weight distribution over the affected leg (in percentage of the total body weight) during static stance measured in four phases for three subjects (\( \bar{x} \) = mean).
Figure 2. Midline deviation from COG during static stance measured in four phases for three subjects. The numeric scores for the midline position of COG in the mediolateral direction is expressed as a percentage of the theoretical limits of stability according to Balance Master System ($\bar{x}$ = mean).
The results of this study, on the basis of visual inspection and statistical analysis of the data for three subjects with hemiplegia, suggest that the application of an intervention program focused on postural control training would have a significant treatment effect on symmetric weight bearing. The mean midline deviation of COG values were 34.05, 50.21, and 29.05 for the first A phase and 9.28, 15.62, and 7.88 for the first B phase.

Discussion

The results of this study, on the basis of visual inspection and statistical analysis of the data for three subjects with hemiplegia, suggest that the application of an intervention program focused on postural control training would have a significant treatment effect on symmetric weight bearing. The mean midline deviation of COG values were 34.05, 50.21, and 29.05 for the first A phase and 9.28, 15.62, and 7.88 for the first B phase.

For the symmetric weight bearing of each subject (see Figure 1), there was a downward trend in the data pattern during the baseline and treatment-withdrawal (A) phases. However, as treatment was introduced in the two B phases, the trend changed direction (i.e., results from the second AB phases paralleled those from the first AB phases). This observation suggests that there was a high degree of reliability for intervention effect on symmetric weight bearing.

During each baseline and treatment-withdrawal phase, most of the mean weight bearing values were 35% to 45% of body weight on the affected limb (see Figure 1). These mean values are low in comparison with the 48% to 54% values reported by Badke and Duncan (1983) or the nearly 50% values reported by Dettmann et al. (1987) for weight distribution in subjects without disabilities. On the other hand, during each intervention phase, the mean weight bearing values were 48% to 50% of body weight for subjects 1 and 3, and 42% to 47% for subject 2, which are similar to the values reported for subjects without disabilities (Badke & Duncan, 1983; Dettmann et al., 1987).

The downward trend of the weight bearing values on the subjects’ affected sides identified in the baseline phase (see Figure 1) were contrary to our belief that the subjects’ performance should at least remain the same or slightly improve in the baseline phase. However, our clinical experience has been that patients with hemiplegia easily adopt any abnormal postural-maintaining mechanism to compensate for their impairments if the postural control training program cannot be started as soon as possible after onset of a CVA.

For the midline position of COG of each subject, the data trend for the first B phase was similar to that of the baseline (first A) phase for each subject, but a drop in the level of the data patterns and a reduction in the mean values of midline deviation from COG were apparent when comparing data across phases (see Figure 2). Although a return to baseline level during the treatment-withdrawal (second A) phase seemed to indicate failure, there was a negative change and a greater magnitude of midline deviation from COG during the second A phase compared with that of the second B phase. Generally, the data points for each subject’s midline position of COG in each phase did not appear stable. This variability in the midline position of COG might be considered an initial instability that would be an inherent characteristic in patients with brain damage during the early weeks or months after onset.

Thus, the positive trend and level changes, as well as the statistically significant improvement of standing posture in all three subjects, would be considered a direct replication across subjects. For single-subject design studies, replication of an intervention in a number of subjects is relevant to evaluating generality (Kazdin, 1982; Ottenbacher, 1986). Consequently, our intervention program proved to have therapeutic effects on postural control in subjects with hemiplegia. This result is consistent with a group-comparison study of the same intervention program in subjects with hemiplegia (Wu, 1990).

Our clinical observations suggest that the intervention program used in this study would contribute to good postural control in patients with hemiplegia if it is used exactly as described. The intervention of sanding while in front of a standing table requires the patient to bilaterally and slowly push forward and pull backward a weighted sander with normal alignment and the trunk firmly fixed. This bilateral loading movement of the upper extremities with symmetric and steady posture would assist the patient in relearning normal motor patterns for standing posture. As a result of this loading movement, the legs would become more accustomed to body weight over them. The intervention of the bean bag game elicits weight transfer over the toes (or forefoot) through forward bending of the trunk to pick up a bean bag placed at an appropriate location. In reaching for the bean bag, the patient needs to bend forward with the head projecting ahead of the toes. As a result of this loading movement, the patient would regain the ability to load over the leg that has a problem bearing weight, whether the leg is on the hemiplegic side or the unaffected side (e.g., a person with pusher syndrome exhibits abnormal weight bearing over the unaffected side).

Conclusion

Sensory and motor deficits are the usual factors implicated in affecting postural abnormality in persons with hemiplegia, but there may be other factors as well. Insecurity caused by poor stabilization and abnormal reaction to
body weight over the impaired or unaffected leg in an antigravity position might also contribute to asymmetric postures, especially during early recovery or rehabilitation after onset of a CVA. An activity-oriented program for normalizing reaction to weight bearing over the impaired or unaffected leg and postural stabilization may have a positive clinical effect on the symmetric stance of persons with hemiplegia. Results of this study suggest that the use of a specific intervention program involving a weight distribution activity and a midline position of COG activity were effective in achieving symmetric stance in persons with hemiplegia. ▲

References


