Research Report

Balance and Mobility Following Stroke: Effects of Physical Therapy Interventions With and Without Biofeedback/Forceplate Training

Background and Purpose. Visual biofeedback/forceplate systems are often used for treatment of balance disorders. In this study, the researchers investigated whether the addition of visual biofeedback/forceplate training could enhance the effects of other physical therapy interventions on balance and mobility following stroke. **Subjects.** The study included a sample of convenience of 13 outpatients with hemiplegia who ranged in age from 30 to 77 years ($\bar{X}$=60.4, SD=15.4) and were 15 to 538 days poststroke. **Methods.** Subjects were assigned randomly to either an experimental group or a control group when the study began, and their cognitive and visual-perceptual skills were tested by a psychologist. Subjects were also assessed using the Berg Balance Scale and the Timed "Up & Go" Test before and after 4 weeks of physical therapy. Both groups received physical therapy interventions designed to improve balance and mobility 2 to 3 times per week. The experimental group trained on the NeuroCom Balance Master for 15 minutes of each 50-minute treatment session. The control group received other physical therapy for 50 minutes. **Results.** Following intervention, both groups scored higher on the Berg Balance Scale and required less time to perform the Timed "Up & Go" Test. These improvements corresponded to increased independence of balance and mobility in the study population. However, a comparison of mean changes revealed no differences between groups. **Discussion and Conclusion.** Although both groups demonstrated improvement following 4 weeks of physical therapy interventions, no additional effects were found in the group that received visual biofeedback/forceplate training combined with other physical therapy. [Geiger RA, Allen JB, O'Keefe J, Hicks RR. Balance and mobility following stroke: effects of physical therapy interventions with and without biofeedback/forceplate training. *Phys Ther.* 2001;81:995–1005.]

Key Words: *Balance, Balance Master, Forceplate, Functional mobility, Hemiplegia, Stroke, Timed "Up & Go" Test, Visual biofeedback.*

Ruth Ann Geiger

Jeffery B Allen

Joanne O'Keefe

Ramona R Hicks

Stroke has been identified as the most prevalent diagnosis among adults who fall.[1] One third to one half of all people over the age of 65 years fall at least once per year.[2] The average increases to 1.7 falls per year for people living in long-term care institutions,[3] with 10% to 25% of these falls resulting in serious medical sequelae.[3] More than 200,000 hip fractures occur annually in the United States as a result of falls,[4] with a subsequent mortality rate of approximately 20% within 6 months.[5] One half of older people who have experienced at least one fall admit having a prolonged fear of falling, and, as a result, 25% of these individuals decrease their activity levels.[6] Subsequently, decreased mobility resulting from fear or injury can cause a decline in independence.

Balance is diminished in people with hemiplegia and hemiparesis.[7,8] Postural sway for patients with hemiplegia can be twice that of their age-matched peers.[9] Symmetry of weight bearing is also impaired following stroke, with patients bearing as much as 61% to 80% of their body weight through their nonparetic lower extremity.[10] In addition, hemiplegia can cause a reduction in patients' *limits of stability*, which is defined as the maximal distance that an individual can shift his or her weight in any direction without loss of balance.

Normal limits of stability describe a theoretical cone extending around a person's feet, with a maximal displacement angle equal to 6 to 8 degrees anteriorly, 4 degrees posteriorly, and 8 degrees laterally to each side.[8,9,11] As a measure of standing postural stability, Dettmann et al[12] calculated a stability index for subjects with hemiparesis and for age-matched control subjects. They defined the *stability index* as the percentage of the base of support over which the subjects could move their center of pressure (COP) during weight shifting without loss of balance. The stability index reported for patients with hemiplegia was only 2.3%, compared with 16.6% for age-matched peers without hemiplegia.[12]

The use of visual biofeedback/forceplate systems for the rehabilitation of patients with hemiplegia has been shown to improve stance symmetry in controlled experiments[13,14] and in 2 experiments with single-subject research designs.[10,15] In controlled experiments, however, such training has not been shown to decrease postural sway more than other physical therapy interventions.[13,14] In case studies, there were reports of carryover from visual biofeedback/force footplate training to motor performance and functional abilities as measured with the Ten-Point Activity of Daily Living Scale and the Rivermead Motor Assessment.[10] Because of the design, however, causality cannot be claimed. The training described in the case report included functional activities such as sit-to-stand transfers as well as stride-stance and step-standing (taking one step forward or backward in standing) on the force footplate. Conversely, results from a similar single-case study design identified no improvement in the functional abilities of either of the study subjects following biofeedback/weight-bearing training, as assessed with the Rivermead Motor Assessment.[15]

Two studies have been performed that compared the effects of biofeedback/force monitor training and the

RA Geiger, PT, MS, is Staff Physical Therapist, Cardinal Hill Rehabilitation Hospital, 2050 Versailles Rd, Lexington, KY 40504 (USA) (ruthann@usa.com). Address all correspondence to Ms Geiger.

JB Allen, PhD, ABPP-CN, is Clinical Neuropsychologist and Assistant Professor, School of Professional Psychology, Wright State University, Dayton, Ohio.

J O'Keefe, PT, PhD, is Educational and Physical Therapist Consultant and Private Practitioner, Chicago, Ill. Dr O'Keefe was Assistant Professor, University of Kentucky, Lexington, Ky, when this study was conducted.

RR Hicks, PT, PhD, is Associate Professor, Division of Physical Therapy, University of Washington, Seattle, Wash. Dr Hicks was Assistant Professor, University of Kentucky, when this study was conducted.

All authors provided concept/research design. Ms Geiger, Dr O'Keefe, and Dr Hicks provided writing, and Dr O'Keefe and Dr Hicks provided consultation (including review of manuscript before submission). Ms Geiger and Dr Hicks provided data analysis and project management. Ms Geiger provided data collection and facilities/equipment, and Dr Hicks provided institutional liaisons. The authors thank Dr Terry Malone and Dr Art Nitz, Department of Physical Therapy, University of Kentucky, for their support and assistance throughout this project. They also thank Thomas Clinch, Eileen Coen, Laura Carter, Debbie Martie, Pam Heissenbuttel, Derrik Born, Lisa Gyorffy Duerler, Tarasa Gabhart, Michelle Ruprecht, Polly Anderson, and Mary Beth Cline for their support, participation, and involvement in this research effort. Most of all, they thank the patients who graciously participated in this study and contributed to the current body of research related to balance and functional mobility intervention strategies in patients who have hemiplegia secondary to stroke.

This study was approved by the Institutional Review Board of the University of Kentucky.

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effects of other therapy on gait performance in patients with hemiplegia secondary to stroke.[14,15] A crossover study by de Weerdt et al[15] demonstrated improvement in stance-phase components of patients' gait (position of center of mass over the foot, knee posture and hip position of the hemiplegic lower extremity) during weeks that included training on a biofeedback/force monitor system; however, no improvement was demonstrated in step length or stance time in this experiment. Similarly, Winstein et al[14] identified no difference in gait speed, stride length, cadence, or cycle time between an experimental group who trained on a visual biofeedback/forceplate and a control group who received other therapy. Additional research indicates that balance performance on biofeedback/forceplate systems correlates well with measures of balance[12] and gait.[8] However, other than the 2 single-subject research design studies mentioned previously,[10,15] no controlled intervention studies have been performed to examine the effectiveness of the addition of biofeedback/forceplate training to other therapy compared with therapy alone in improving balance and mobility. Therefore, the purpose of this study was to compare outcomes (using the Berg Balance Scale[16] and the Timed "Up & Go" Test[17,18]) following balance and mobility retraining by physical therapy with and without the addition of NeuroCom Balance Master* training in 2 groups of patients who had hemiplegia secondary to stroke.

Method

Subjects

Our subjects were 9 male and 4 female patients with hemiplegia secondary to stroke who had been referred by a physician for outpatient physical therapy evaluation and intervention. The patient population in this study was a sample of convenience made up of subjects who were between 30 and 77 years of age ($\bar{X}$=60.4, SD=15.4). The subjects ranged from 15 to 538 days poststroke ($\bar{X}$=115, SD=148.9, median=46) (Tab. 1). The primary inclusion criteria were that subjects have hemiplegia as a result of stroke and that they be able to maintain a stationary standing position with or without an assistive device for a minimum of 2 consecutive minutes without manual assistance. Seven of the 13 subjects were using an assistive device at study initiation (Tabs. 2 and 3).

If patients met the study criteria and agreed to participate, they were randomly assigned to either an experimental group or a control group by a coin toss. Each subject was able to follow instructions and gave informed consent by signing an approved consent form; thus, the rights of human subjects were protected.

* NeuroCom International Inc, 9570 SE Lawnfield Rd, Clackamas, OR 97015.

Table 1.
Demographic Data of Study Subjects

	Total	Control Group	Experimental Group
No. of subjects	13	6	7
Age (y)			
$\bar{X}$	60.4	58.7	61.8
SD	15.4	14.8	16.9
Range	30–77	38–77	30–77
Days poststroke			
$\bar{X}$	115.5	133.8	99.9
SD	148.9	203.4	96.0
Range	15–538	15–538	26–239
Median	46	39.5	61
Sex			
Male	9	4	5
Female	4	2	2
Side of hemiplegia			
Right	5	3	2
Left	8	3	5

Psychological Testing

Because patients with either right or left hemiplegia were included in the study, there was a concern that stroke related cognitive or visual-perceptual issues might affect the subjects' ability to use the Balance Master. Therefore, testing was performed by a psychologist initially to ascertain whether the experimental and control groups were equal with respect to the cognitive skills tested. A basic cognitive screening of such domains as orientation, attention, comprehension, repetition, naming, constructional ability, calculation and reasoning, sequencing, and the ability to switch cognitive sets while visually searching or scanning was administered. Given the visual-perceptual demands of the intervention, more comprehensive testing of visual discrimination, concentration, sequencing, and set shifting was also performed using Benton's test for visual discrimination,[19] the Neurobehavioral Cognitive Status Exam,[20] the mental control subtest of the Wechsler Memory Scale,[21] and the Trail-Making Test from the Halstead-Reitan Battery.[22]

The demographic data (Tab. 1) indicated that both groups were similar with respect to age, number of days poststroke, and educational level (*t* test; *P*=.726, .700, and .910, respectively). In addition, no differences were identified between groups with respect to the cognitive and visual-perceptual tests performed (*P*=.178–.880), although individual subject results ranged from normal to severe impairment. A comparison of the full-field visual-perceptual performance of subjects with right versus left hemiplegia also revealed no statistically significant differences (*P*=.172–.821).

Table 2.
Control Group Subjects' Data

Subject No.	1	2	3	4	5	6
Sex	M	M	F	M	F	M
Age (y)	65	45	58	38	69	77
Education (y)	14	9	12	12	17	6
Side of hemiplegia	R	L	L	R	R	L
Days since stroke	46	15	144	33	27	538
Physical therapy visits/week	3	2	2	2	2	2
Berg Balance Scale						
Pretreatment score	32/56	55/56	37/56	49/56	45/56	50/56
Posttreatment score	55/56	56/56	39/56	55/56	54/56	55/56
Timed "Up & Go" Test[a]						
Pretreatment time (s)	25	10	59	16.4	18	13.34
Posttreatment score (s)	9.25	9	35	8	13	15
Assistive device pretreatment	RW	None	SBQC	None	None	Straight cane
Assistive device posttreatment	None	None	SBQC	None	None	None

[a] RW=rolling walker, SBQC=small-base quad cane, None=no assistive device.

Equipment

Equipment used in the experimental condition included the Balance Master, a dual forceplate system composed of 4 load cells that detect pressure, connected to a 486 DX IBM-compatible computer and monitor.[23] The NeuroCom Balance Master, according to the manufacturer, is supposed to provide a visual representation of a person's center of gravity. Menu-driven exercise tasks depict still or moving targets on the computer monitor. The subjects were instructed to maintain or shift their weight, as appropriate, to make the representation of their center of gravity reach the target(s) presented visually. The Balance Master is equipped with internal monitors of calibration. According to the manufacturer, if calibration errors occur during initial computer power-up or during training, an error message is displayed.

Equipment used for other physical therapy interventions and administration of the tests included a 10.16-cm-wide (4-in-wide) balance beam, small and large rocker boards, a Swiss ball, firm and compliant floor mats, a 48.26-cm-high (19-in-high) treatment mat, a 16.51-cm-high (6.5-in-high) stool, a chair with armrests (seat-to-floor height=44.45 cm [17.5 in], armrest height=66.04 cm [26 in]), stairs, gait belts, a tape measure, appropriate assistive devices, and ankle-foot orthoses (as needed).

Measures

Timed "Up & Go" Test. Subjects in the control and experimental groups were tested by a therapist initially and after 4 weeks of physical therapy using the Timed "Up & Go" Test. In this test, the examiner times the patient as he or she performs the following activity: from a sitting position in a standard-height armchair, the patient independently stands up, walks 3 m (with assistive device, as needed), turns around, walks back, turns around, and sits down again.[17,18] Some authors[17,24,25] contend that the Timed "Up & Go" Test provides valid measurements of mobility and that the measurements correlate well with Berg Balance Scale scores and with functional capacity as measured by the Barthel Index. Measurements obtained with the Timed "Up & Go" Test have been shown to have acceptable interrater and intrarater reliability.[17,25] Podsiadlo and Richardson[17] contend that the Timed "Up & Go" Test has content validity, in that it evaluates a well-recognized series of maneuvers used in daily life, and that it has acceptable concurrent validity because the measurements correlate well with data obtained with more extensive measures of balance, gait speed, and functional abilities. Adults without neurological impairments who are independent with balance and mobility skills are able to perform the Timed "Up & Go" Test in less than 10 seconds.[24]

Adults who take longer than 30 seconds to complete the test have been found to be dependent for most activities of daily living and mobility skills.[17,24] Because high interrater reliability (intraclass correlation coefficient=.99)[17] has been established for measurements obtained with this test, we did not examine reliability.

Berg Balance Scale. Subjects in both groups were assessed by a therapist initially and after 4 weeks of intervention using the Berg Balance Scale. Because the Berg Balance Scale has been shown to yield data that have validity, strong internal consistency, and excellent intrarater and interrater reliability (intraclass correlation coefficients of .99 and .98 respectively), this scale is widely used as an outcome measure for balance performance.[8,16,24–26] Berg Balance Scale scores correlate well with measurements obtained with other clinical balance scales for both elderly subjects and for patients with hemiplegia secondary to stroke and with measurements

Table 3.
Experimental Group Subjects' Data

Subject no.	7	8	9	10	11	12	13
Sex	F	M	M	F	M	M	M
Age (y)	65	48	72	68	30	77	73
Education (y)	14	8	16	14	10	12	6
Side of hemiplegia	L	R	L	L	L	R	L
Days since stroke	239	238	26	61	69	36	30
Physical therapy visits/week	2	3	2	3	3	2	2
Berg Balance Scale							
Pretreatment score	41/56	55/56	54/56	33/56	50/56	48/56	45/56
Posttreatment score	47/56	53/56	52.5/56	43/56	56/56	53/56	51/56
Timed "Up & Go" Test[a]							
Pretreatment time (s)	24	17.38	18.84	42.4	23	11.44	23.29
Posttreatment score (s)	No data	16.75	16.91	39.75	9.4	8.4	11
Assistive device pretreatment	None	SBQC	SBQC	RW	None	None	RW
Assistive device posttreatment	None	SBQC	SBQC	SBQC	None	None	Straight cane

[a] RW=rolling walker, SBQC=small-base quad cane, none=no assistive device.

of gait speed in patients with hemiplegia.[8,16,17] In addition to construct validity, the Berg Balance Scale demonstrates criterion validity to the extent that its measurements can be used to differentiate patients who need to use a walker or a cane from those who do not need to use an assistive device.[25] However, the Berg Balance Scale also has limitations because it may have a ceiling effect for patients with higher-level neurological impairments, lacks a gait assessment component, and measures primarily anticipatory, but not reactive, postural responses necessary for balance.

The Berg Balance Scale measures a person's ability to perform 14 balance activities: sit and stand unsupported, transfer from a sitting position to standing position and from a standing position to a sitting position, transfer to and from a chair and mat, stand unsupported with eyes closed, stand unsupported with feet together, reach with an outstretched arm, squat and pick up an object from the floor, stand and turn to look over each shoulder, stand and turn 360 degrees toward the right and left, stand and alternately place one foot up on a step, maintain tandem stance, and stand on one lower extremity. Each of the 14 test items requires the ability to balance and can be considered a reflection of either functional activities or components of everyday functional activities such as stair climbing or donning pants in a standing position. Scores range from 0 to 4 points on each of the 14 test items. Possible total scores range from 0 to 56 points, with higher scores indicating greater balance ability and functional independence with respect to the activities tested. Although the Berg Balance Scale cannot be used as a predictor of falls (because it lacks sensitivity), researchers have found that patients who score 45 or more out of 56 points have a high probability of *not* falling and are less likely to use an assistive device than those who score below 45 points.[26]

In our study, all of the therapists were instructed in the use of the Berg Balance Scale and were given an opportunity to observe its administration by a physical therapist with 1½ years of experience using this scale and to practice its administration prior to testing of subjects. According to the directions for the Berg Balance Scale, people are not permitted to use an assistive device while performing the test, but we allowed the subjects in our study to wear an ankle-foot orthosis, if needed, during both pretreatment and posttreatment administration of the test. Whenever possible, a physical therapist who was unaware of the subjects' group assignments scored the subjects' week-4 performance of the Berg Balance Scale simultaneously with the treating therapist who administered the test. Attempts were also made to videotape the Berg Balance Scale measurements if a masked therapist was not available to score the test.

Physical Therapy Intervention Procedures

Seven physical therapists, one physical therapy intern, and one physical therapist assistant were involved in the study, providing the physical therapy interventions and administering the Berg Balance Scale and the Timed "Up & Go" Test to the subjects throughout the 4-week course of the study. The experience level of these therapists ranged from 0 to 19 years, with an average experience level of 3.4 years.

Physical therapy interventions. The physical therapy interventions for both the control and experimental groups included physical therapy techniques aimed at improving muscle force, range of motion, balance, and mobility. These interventions included mat activities (stretching and strengthening), weight bearing or shifting and standing lower-extremity exercise in parallel bars, and balance activities such as rocker-board and unilateral stance activities, tandem stance and ambulation activities, braiding, balance beam activities, and sitting on a Swiss ball with eyes open and eyes closed, as appropriate.

Training in functional activities such as bed mobility, scooting in a sitting position, standing, reaching, transfers, stair climbing, and gait on even surfaces and on uneven or compliant surfaces was also included. During training, subjects were offered as much assistance as was necessary to prevent a fall. Therapy sessions were tailored to each subject's needs, as were the home exercise programs that subjects in both groups were encouraged to perform daily.

Records were kept of the amount of time spent on each therapeutic activity. Nevertheless, because the intervention sessions were individualized for each subject based on his or her impairments, functional limitations, disability, and personal treatment goals, no effort was made to ensure that the same amount of time was spent on any particular activity from subject to subject or that the same mix of activities was performed. As is the practice in our clinic, the physical therapists selected, administered, and progressed the interventions as appropriate for each subject. The control group received only the physical therapy interventions described, which were provided 2 or 3 times per week in 50-minute sessions.

Balance Master Training Protocol. The physical therapists and the physical therapist assistant who worked with subjects on the Balance Master were trained and competent in its use. Subjects in the experimental group received physical therapy interventions 2 or 3 times per week for 35 minutes and trained on the Balance Master for 15 minutes of massed practice for each 50-minute session. Subjects who trained on the Balance Master wore shoes and stood with one foot on each forceplate according to the manufacturer's instructions, which take height into consideration.[23] The forceplate, according to the manufacturer, works optimally for people who weigh between 18 and 136 kg (40–300 lb); the weight of each subject fell within this range.

Subjects were allowed to use a walker or cane, if necessary, during Balance Master training. Typically, canes were used with their tips positioned on the platform, and walkers straddled the platform. A therapist directly supervised each subject during Balance Master training. We attempted to ensure the subjects' safety at all times, but physical assistance was not provided during training unless it was necessary to prevent a fall. The Balance Master training protocols were individualized and progressed by increasing the limits of stability and the pace (time allowed per weight shift) to challenge the subjects' weight-shifting abilities as their balance improved over the course of the 4-week study.

A training session typically included a brief warm-up period of stationary standing with eyes open and eyes closed; however, most time was spent on balance retraining. Emphasis was placed on anterior, posterior, and lateral and diagonal weight shifts to the subject's affected side as well as weight shifting sequentially to 8 targets forming an ellipse. The majority of subjects did not require rest breaks during the 15-minute training session, and most subjects worked at 50% to 75% of their limits of stability with 5- to 7-second pacing. In this experiment, the Balance Master was used for physical therapy intervention purposes only, not for assessment; therefore, data obtained from the Balance Master were not analyzed statistically. Subjects in the experimental group did not have exposure to the Balance Master outside of the therapy sessions described.

As an example of one subject's physical therapy intervention and progression, subject 13 initially scored 45/56 on the Berg Balance Scale and performed the Timed "Up & Go" Test in 23.29 seconds using a rolling walker. During one session in the second week, he spent equal amounts of time in sit-to-stand activities, gait training, patient education related to a home exercise program, and home safety, performing activities requiring advanced gross motor skills (braiding and ambulating backward and sideways with assistance), and then spent 15 minutes training on the Balance Master. During one session in his last week of therapy, he spent equal amounts of time in gait training and activities requiring advanced gross motor skills, but he required less assistance than previously. Instead of performing sit-to-stand activities, he trained in standing rocker-board activities. This subject also spent equal amounts of time on floor-to-stand transfers and training on the Balance Master. At the end of the fourth week of therapy, this subject's Berg Balance Scale score had improved from 45/56 to 51/56. He also improved with respect to balance and efficiency on the Timed "Up & Go" Test, from requiring 23.29 seconds to perform the test initially using a rolling walker to requiring only 11 seconds using a straight cane following 4 weeks of physical therapy (Tab. 3).

Data Analysis

Study data were analyzed using the SPSS statistical package.† Tests applied to the data included the Levene test for equality of variances to determine whether equal variance between groups could be assumed. Equal variances between groups support the use of conventional statistical analyses, whereas without this assumption, transformation of the data may be required

† SPSS Inc, 444 N Michigan Ave, Chicago, IL 60611.

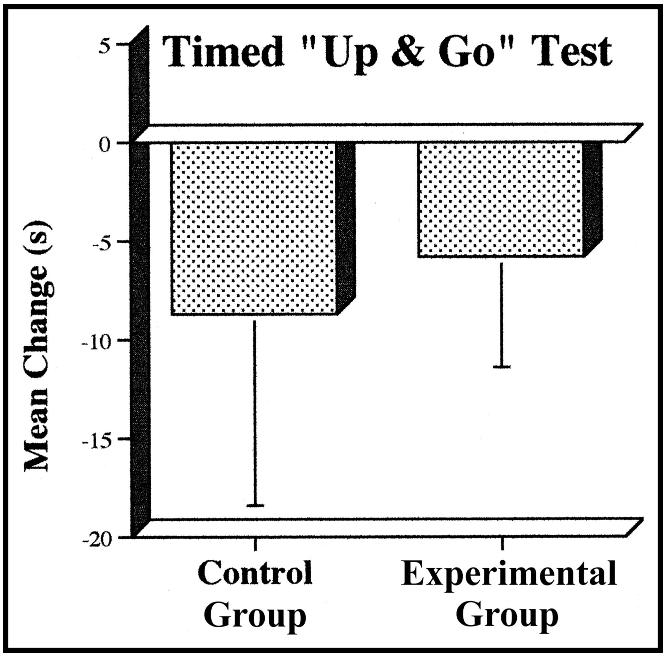

Figure 1.
Mean (±SD) changes in Timed "Up and Go" Test scores for the control group (physical therapy only) and the experimental group (physical therapy combined with Balance Master training). The improvements observed following physical therapy interventions were not different between groups.

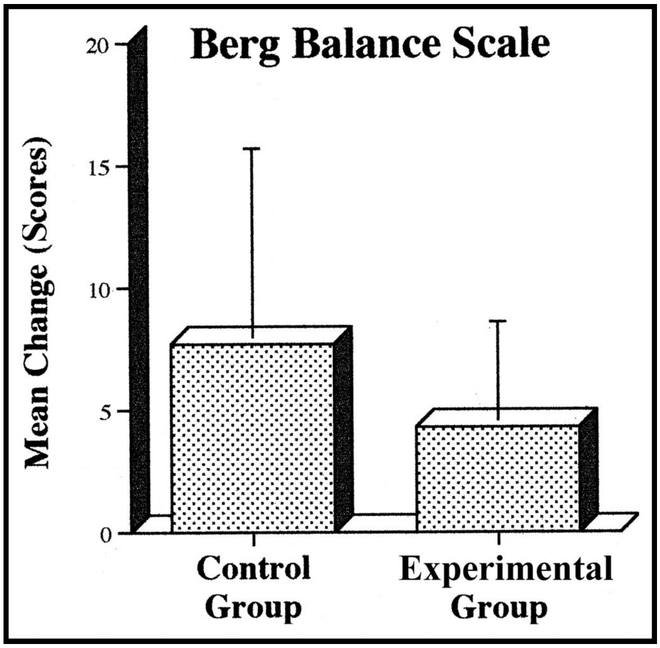

Figure 2.
Mean (±SD) changes in Berg Balance Scale scores for the control group (physical therapy only) and the experimental group (physical therapy combined with Balance Master training). The improvements observed following physical therapy interventions were not different between groups.

prior to making comparisons. Independent-samples t tests and paired t tests allowed for comparisons between the pretreatment and posttreatment test results between groups and within groups, respectively. The Mann-Whitney rank sum test was used to compare test results between groups for ordinal data such as the Berg Balance Scale scores. The Spearman rho test for nonparametric data was used for correlation analysis between groups and between measures. Prior to data analysis, the level of significance was established at $P<.05$.

Results

Results of the Levene test for equality of variances were not significant for the Berg Balance Scale ($P<.350$) or for the Timed "Up & Go" Test ($P<.272$), indicating that equal variance between groups could be assumed for both measures. When comparing the mean pretreatment and posttreatment differences for the experimental and control groups, an independent-samples t test identified no difference between the control group ($\overline{X}=-8.79$ seconds, SD=9.68 seconds) and the experimental group ($\overline{X}=-5.69$ seconds, SD=5.64 seconds) for the Timed "Up & Go" Test ($P<.514$) (Fig. 1). The Mann-Whitney test also did not identify a difference between the control group (mean rank of 7.50) and the experimental group (mean rank of 6.57) with respect to the mean difference of scores for the Berg Balance Scale ($P<.663$) (Fig. 2). The probability values listed were for 2-tailed tests.

Because no difference was identified between the control and the experimental groups, both groups' values were combined to analyze the overall improvement of all subjects and to allow correlation analyses for the 2 measures used. A t test for paired samples (difference between pretreatment and posttreatment scores) indicated that both groups of subjects combined demonstrated improvement after physical therapy interventions with respect to both the Berg Balance Scale (mean [±SD] pretreatment score of 45.69±7.93 versus mean posttreatment score of 51.54±5.41, $P<.006$) and the Timed "Up & Go" Test (mean pretreatment score of 23.08±13.7 seconds versus mean posttreatment score of 14.62±11.18 seconds, $P<.008$) (Fig. 3).

To examine the results from the entire study population grouped together, we used a Spearman rho correlation. Pretreatment scores from both measures correlated with each other ($r=-.761$, $P<.01$) (Fig. 4), as did posttreatment scores ($r=-.667$, $P<.05$) (Fig. 5). Berg Balance Scale versus Timed "Up & Go" Test mean difference scores, however, did not correlate with each other ($r=-.504$) (Fig. 6). The correlations between the data obtained from the cognitive and visual-perceptual testing and the 2 measures led to only one correlation, and that was between the change in Timed "Up & Go" Test scores (difference of pretreatment times minus posttreatment times) and scores from Benton's visual form discrimination test[19] ($r=.716$, $P<.03$).

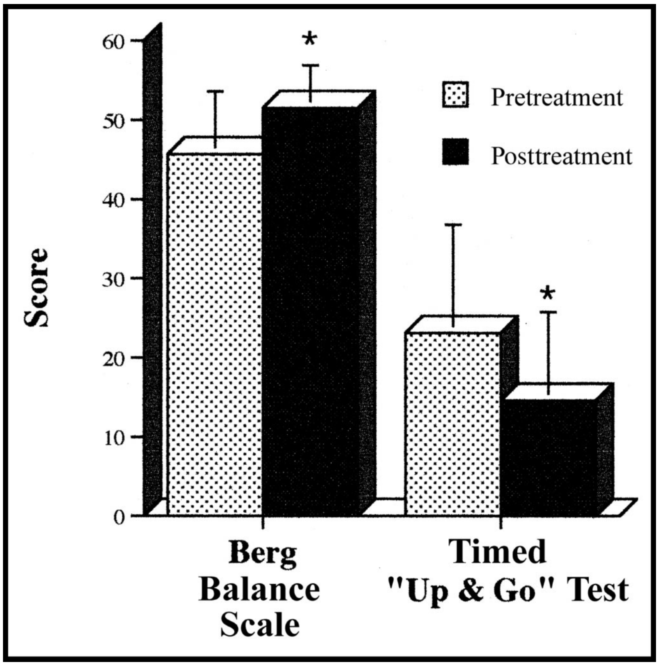

Figure 3.
A comparison of mean (±SD) Berg Balance Scale and Timed "Up & Go" Test scores before and after 4 weeks of physical therapy interventions for all subjects demonstrated improvements following interventions. Asterisk indicates $P<.05$ following interventions.

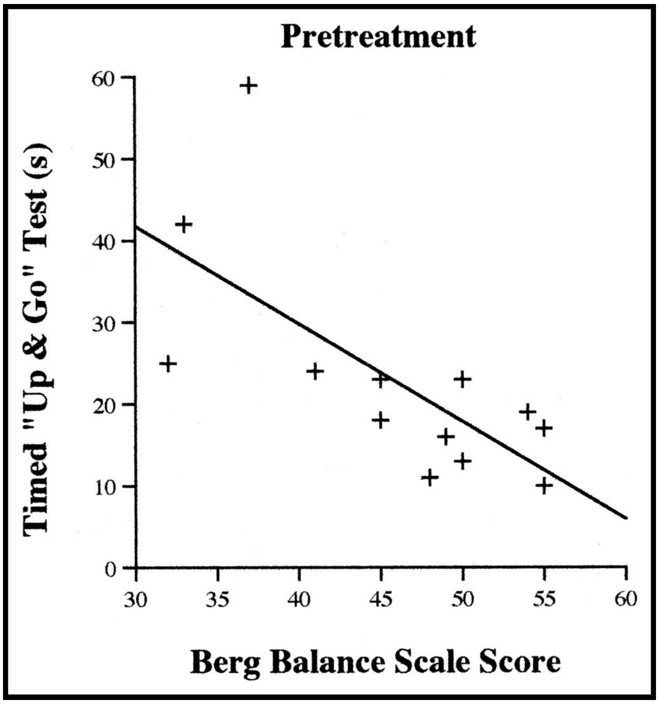

Figure 4.
There is a negative correlation ($r=-.761$, $P<.01$) between the pretreatment Berg Balance Scale and Timed "Up & Go" Test scores.

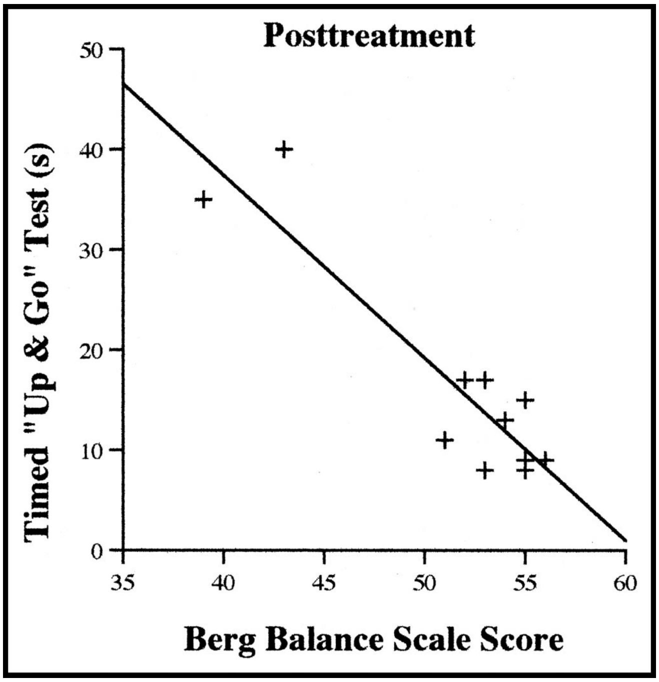

Figure 5.
There is a negative correlation ($r=-.667$, $P<.05$) between the posttreatment Berg Balance Scale and Timed "Up & Go" Test scores.

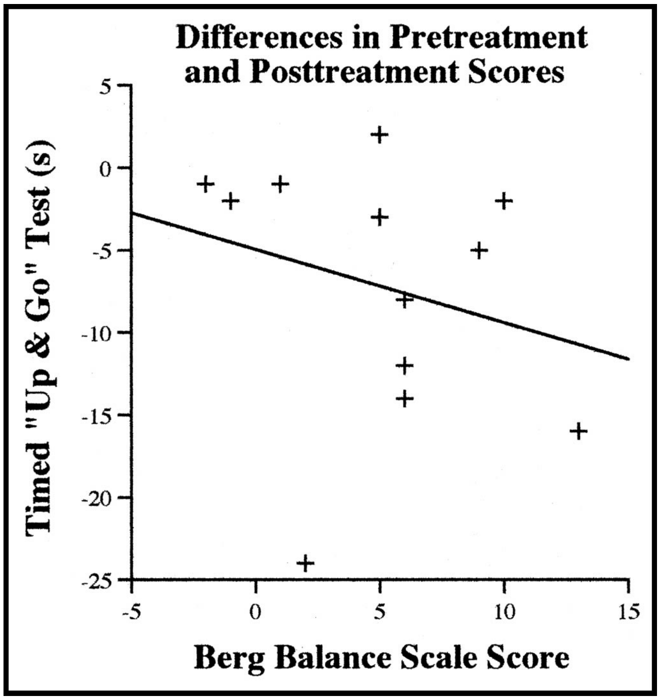

Figure 6.
Changes in pretreatment and posttreatment Berg Balance Scale scores did not correlate to changes in Timed "Up & Go" Test scores ($r=-.505$).

Discussion

Although research indicates that the use of visual biofeedback/forceplate training improves stance symmetry in subjects with hemiplegia following stroke,[10,13–15] further research has been needed to examine whether the inclusion of visual biofeedback/forceplate training would also have an impact on higher-level multifactorial abilities such as balance and mobility skills. To our knowledge, ours is the only controlled study that investigated the effects of the combination of visual biofeedback/forceplate training and other physical therapy compared with physical therapy alone on balance and mobility skills.

Our major finding was that visual biofeedback/forceplate training combined with conventional physical therapy did not enhance the effects of conventional physical therapy on balance and functional mobility skills in outpatients with hemiplegia secondary to stroke. Our findings are in general agreement with other researchers who reported a lack of an effect on gait speed[14] or functional abilities[15] following biofeedback/forceplate training. However, our findings are in contrast to those of Sackley and Baguly,[10] who reported greater improvements in functional abilities, including transfers and gait, following treatment that included biofeedback/forceplate training. Although there are many possible reasons for the lack of an effect in our study, one explanation is that balance retraining is very context- or task-specific.[27] It is likely that weight-shifting tasks performed on a biofeedback/forceplate system, although helpful in improving stance symmetry and weight-shifting abilities, do not necessarily correspond to improvements in gait and other higher-level mobility and balance tasks. The smallness of our sample size may have contributed to a type II statistical error, and further research with larger sample sizes can exclude that possibility.

Cognitive and visual-perceptual testing performed by a psychologist revealed no differences between groups (2 subjects in the experimental group and 1 subject in the control group were not tested initially). In addition, no differences were detected between the performances of subjects with right versus left hemiplegia. Although no difference was found between groups, it is possible that visual-perceptual deficits had a negative impact on some of the subjects' ability to train on the Balance Master.

Although the Rivermead Stroke Assessment[28] and the Ten-Point Activity of Daily Living Scale[29] had been used in previous single-case study designs,[10,15] they include several tasks that are not specific to balance and mobility, such as eating, drinking, grooming, and upper-extremity coordination and fine-motor control tasks. The Berg Balance Scale and the Timed "Up & Go" Test, therefore, were chosen as the assessment tools in this experiment because we believe they are measures of balance and mobility that relate to real-life meaningful activities such as transfers, stair climbing, and gait. These measures are also widely used, easy to administer, and yield measurements that have known reliability and validity.[8,16–18,24–26]

For the study population as a whole, the Berg Balance Scale versus Timed "Up & Go" Test pretreatment scores correlated to each other, as did the posttreatment scores. These correlations agree with one-time testing results of previous experiments by Podsiadlo and Richardson[17] and Berg et al[25] involving the same 2 measures. The mean difference scores (difference between pretreatment and posttreatment scores) for the entire study population, however, did not correlate to each other, suggesting that some subjects made greater gains on one measure than on the other measure.

The intent of the original study design was to have all posttreatment Berg Balance Scale testing performed by a masked evaluator or to have the test administration videotaped for future analysis by a masked evaluator. This was not always possible, however, because of scheduling difficulties and time constraints in the outpatient setting. Only 3 of the 13 Berg Balance Scale assessments performed after 4 weeks of treatment were scored by a physical therapist who was unaware of the subjects' group assignments. However, in these 3 instances, the simultaneously scored results from both the masked evaluator and the unmasked treating physical therapist were highly consistent (0- to 2-point differences in scores out of a possible total score of 56 points), as would be expected given the test's excellent interrater reliability.[8] Nevertheless, consistent masking and assessment of the evaluators' ability to accurately perform the tests would have added to the strength of our study. Similarly, the small number of subjects increased the likelihood of a type II error in accepting the null hypothesis and was another limitation of our study.

The initial research study plan was to use the Berg Balance Scale and the Timed "Up & Go" Test to assess the subjects initially and after 4 weeks and 6 weeks of physical therapy. However, by the sixth week of therapy, 8 of the 13 study participants (62%) had been discharged from the outpatient program. Therefore, data analysis was performed using the scores obtained with both measures after 4 weeks of treatment as the final scores (Tabs. 2 and 3).

All subjects required 10 seconds or longer to complete the Timed "Up & Go" Test initially, indicating that all subjects had impairment with respect to the activities assessed by the test.[17,25] However, following 4 weeks of physical therapy interventions, 2 of the 13 subjects had changed from using rolling walkers to using canes, and 2 subjects had progressed to walking without assistive devices (Tabs. 2 and 3). In addition, at the initial assessment, none of the subjects scored 56/56 points on the Berg Balance Scale, indicating that all subjects also had balance deficits. By the final assessment, however, 2 subjects (one in the control group and one in the experimental group) scored full marks. Thus, the Berg Balance Scale proved to have a ceiling effect, which prevented demonstration of further improvements of balance for these 2 subjects.

We do not consider the lack of tight control on the amount of time spent and the specific tasks performed during the physical therapy intervention sessions to be a major study weakness, because our purpose was to determine whether there was an additive effect with Balance Master training, rather than to demonstrate that it was better than another specific intervention, and it represents our typical clinical practice in which interventions are tailored to the individual patient's most obvious balance and mobility needs. In addition, specific therapist influence can be ruled out because each of the 9 therapists involved in physical therapy delivery and measure assessment had equal opportunities to work with both groups of subjects. The effectiveness of our interventions is supported by the improvement of both groups of subjects over the course of the 4-week study, regardless of group assignment.

Fifteen-minute training periods on the Balance Master were chosen based on a similar controlled study by Shumway-Cook et al[13] in which they compared the effects of biofeedback/forceplate training versus other physical therapy interventions on postural sway in 16 patients with hemiplegia. This appeared to be an appropriate duration for the Balance Master training because, by the end of the 15 minutes, most patients seemed to be ready to move on to other activities. Furthermore, the expense and size of the equipment make Balance Master training impractical for home use; thus, opportunity to use the equipment was limited to the duration of each patient's course of outpatient physical therapy. However, we believe a positive feature of the Balance Master training program was that many of our subjects would have been able to practice on this equipment independently in the clinic, making it less labor intensive than many physical therapy activities.

When the results from all subjects were grouped together and correlation analysis was performed between the cognitive and visual-perceptual data and the 2 measures, the only correlation identified was a positive correlation between Benton's visual form discrimination test and change in Timed "Up & Go" Test scores. This positive correlation indicates that subjects with good visual form discrimination tended to make greater gains in performance of the Timed "Up & Go" Test following physical therapy interventions. Further research on the relationship between cognitive and visual-perceptual deficits and the effectiveness of Balance Master training following stroke might help to identify individuals who are most likely to benefit from this type of training.

Including patients who ranged from 15 to 538 days poststroke was less than ideal because, although functional improvement may continue to some degree over time,[30] the majority of neurologic recovery is likely to occur in the first 1 to 3 months following stroke.[30] Nevertheless, although a wide range in days poststroke was represented by our subject population, both the control and experimental groups were found to be similar with respect to time poststroke, as well as to age and educational level, as evidenced by the lack of differences in the 2 groups' demographic profiles (Tab. 1). Further research that includes groups of patients with a more narrow range of times poststroke (eg, $<$3 months, 3–6 months, 6–12 months, and $>$12 months) may yield additional information with regard to the effectiveness of biofeedback/forceplate training for improving balance and mobility skills in groups of patients with different levels of chronicity following stroke.

When the subjects were evaluated as a whole (control and experimental groups were collapsed into one group), improvements in the Berg Balance Scale and Timed "Up & Go" Test scores (Fig. 3) were evident following physical therapy interventions. These results suggest that physical therapy is helpful for improving balance and mobility of patients who have hemiplegia as a result of stroke. However, because there was no untreated control group to rule out spontaneous recovery, we cannot demonstrate the effectiveness of the physical therapy interventions. Having 2 additional control groups, one that did not receive intervention and one that received only Balance Master training, would have added to the power of this study. In our study, however, because all subjects had been referred for physical therapy interventions, we believed that we could not ethically withhold therapy or provide biofeedback/forceplate training alone.

Conclusion

Our results indicate that there was no benefit of Balance Master training when administered in combination with other physical therapy interventions, compared with physical therapy alone, when provided 2 to 3 times per week over a 4-week period to outpatients with hemiplegia secondary to stroke. However, improvements were observed with respect to both the Berg Balance Scale and the Timed "Up & Go" Test for the subjects as a whole, suggesting that early as well as delayed physical therapy interventions can be effective in improving balance and mobility in patients with hemiplegia. Spontaneous recovery cannot be ruled out as the reason for the subjects' improvement, however, because an untreated control group was not included in this study. Further research is needed to identify specific interventions that enhance recovery of function after stroke.

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