Balance Performance Among Noninstitutionalized Elderly Women

Descriptive data were collected regarding static standing balance of 71 noninstitutionalized elderly women as they performed two timed balance tests. All subjects performed the sharpened Romberg test and the one-legged stance test on each foot in four test conditions: 1) eyes open, 2) eyes closed, 3) shoes on, and 4) shoes off. Subjects were grouped and analyzed according to the following age ranges: 1) 60 to 64 years, 2) 65 to 69 years, 3) 70 to 74 years, 4) 75 to 79 years, and 5) 80 to 86 years. The best time of three trials was used for data analysis. The maximum balance time for the sharpened Romberg test was 60 seconds. For the one-legged stance test, a maximum balance time was 30 seconds. No significant difference was found between right and left or dominant and nondominant limbs while performing the one-legged stance test. No significant difference was found in mean balance time between subjects who had fallen versus those who had not fallen, nor between shoes-on and shoes-off test performance. Subjects' performance on the eyes-open test was consistently superior to their eyes-closed test performance ($p < .0001$). The one-legged stance test mean balance time decreased significantly as age increased. More subjects reached the maximum balance time on the sharpened Romberg test than on the one-legged stance test. The results of this study indicate that additional research is needed in the area of balance maintenance among the elderly population. [Briggs RC, Gossman MR, Birch R, et al: Balance performance among noninstitutionalized elderly women. Phys Ther 69:748–756, 1989]

Randall C Briggs
Marilyn R Gossman
Robert Birch
Judith E Drews
Shirley A Shaddeau

Key Words: *Aging; Equilibrium; Geriatrics; Tests and measurements, functional.*

Maintaining balance in the human body is an intricate process. Visual, vestibular, and other somatosensory stimuli contribute information about the body's position in space and its center of gravity. Coordinated responses to stimuli must be transmitted to the appropriate muscles to correct or maintain balance. In this article, the process of keeping the body in an upright position is referred to as *balance maintenance* or *equilibrium*.[1,2]

Elderly women, especially those 65 years of age or older, are known to be at high risk of disequilibrium.[3,4] This loss of balance is correlated with an increased number of falls.[5] Although not every loss of balance results in a fall and not every fall results in an injury, falls frequently lead to serious complications, especially among the elderly.[6] Since 1923, only motor vehicle accidents have

R Briggs, MS, PT, is Staff Physical Therapist, Carlisle Hospital, 246 Parker St, Carlisle, PA 17013, and Contract Director of Physical Therapy, Carlisle Leader Nursing and Rehabilitation Center, Carlisle, PA 17013. Address correspondence to Mr Briggs at 2136 N 4th St, Harrisburg, PA 17110 (USA).

M Gossman, PhD, PT, is Professor and Director, Division of Physical Therapy, The University of Alabama at Birmingham, University Station, Birmingham, AL 35294.

R Birch, PhD, is National Biotherapy Study Group Statistician, Biological Therapy Institute, Hospital Drive, Franklin, TN 37064. He was Assistant Professor, Department of Biostatistics and Biomathematics, The University of Alabama at Birmingham, when this study was conducted.

J Drews, PhD, PT, is Coordinator of Physical Therapy, Sparks Center, PO Box 313, The University of Alabama at Birmingham.

S Shaddeau, MMSc, PT, is Associate Professor, Division of Physical Therapy, The University of Alabama at Birmingham.

This study was completed in partial fulfillment of the requirements for Mr Briggs's master's degree, The University of Alabama at Birmingham.

This article was submitted September 9, 1987; was with the authors for revision for 54 weeks; and was accepted March 14, 1989.

surpassed falls as the most frequent cause of accidental death in the United States.[7] Injury to elderly individuals secondary to a fall may result in a decrease of their quality of life, permanent limitation of their activities, or death.[8] Unfortunately, those individuals who have fallen once are prone to fall again.[3]

Many anatomical and physiological changes have been suggested as reasons for the decrease in equilibrium found in the elderly population.[9–11] Abnormalities have been identified in both the central and the peripheral nervous systems.[12–15] Circulatory changes (eg, atherosclerosis) may reduce blood flow to the brain stem, cerebellum, or cerebrum, potentially resulting in ischemic signs and symptoms or lesions of the nervous system.[13] Musculoskeletal abnormalities in the cervical region may affect the perception of the head's position in space.[16] Muscle atrophy and weakness, especially of the postural muscles, are prevalent in the aged.[17–20]

Numerous pathological conditions have been linked to balance problems. Inner ear or vestibular disorders, neurologic disease processes or injuries, and hypertension or circulatory problems are recognized as factors that can contribute to disequilibrium.[21] The increased use of and sensitivity to prescription medications by the elderly population makes them more susceptible to adverse drug reactions and interactions, which can result in dizziness, loss of balance, and falls.[22]

Tests used to evaluate the ability of a subject to maintain balance were developed as early as 1851 (ie, the Romberg test).[23] Since that time, a wide variety of balance tests and their modifications have been used. In the original Romberg test, the subjects stood with their feet close together. The examiner observed the amount of body sway exhibited by the subjects, first as the subjects stood with their eyes open and then with their eyes closed.

The one-legged stance test (OLST), also referred to as the Solec test, and the sharpened Romberg test (SR) have been used as substitutes for the Romberg test by some clinicians.[11] The OLST requires the subject to maintain balance while standing on one leg, whereas the SR requires the subject to maintain balance while standing in a tandem heel-to-toe position.[11]

The OLST is more difficult for the subject to perform than either the SR or the Romberg test because of the decreased area of weight bearing and the narrowed base of support.[11] Developmentally, the test position for the SR is generally considered a more progressive posture requiring a higher skill level than the Romberg test position.[24] Previous studies have used a maximum testing period of 30 seconds for the OLST and 60 seconds for the SR and the Romberg test.[9,11]

Although numerous standing balance tests are currently used to determine balancing abilities, data regarding the elderly population's performance on these tests are scarce and incomplete. Some studies have examined the decline of equilibrium accompanying aging, but descriptive information is not available for each specific test.[9,10]

The purposes of this study were to 1) collect balance data on healthy, elderly women using two static balance tests; 2) determine the relationship between the balance times and falls; and 3) determine the effect of wearing shoes on balance. Evaluation of these data could lead to a better understanding of the balance reactions of elderly women and may assist in the development and analysis of treatment programs to improve balance and prevent falls.

Four research hypotheses were posed. First, a difference would be found between the proportion of subjects able to reach maximum balance times for the SR and the OLST. Second, balance time would decrease as age increases among the elderly. Third, a negative relationship exists between a history of falls and balance time. Fourth, wearing shoes would affect balance time.

Method

Subjects

Healthy, female subjects between 60 and 86 years of age were recruited from local church groups, senior citizen centers, The University of Birmingham at Alabama, retirement apartment complexes, and nutrition centers in the community. Subjects had to be independent in activities of daily living and able to walk without an assistive device. Volunteers with serious musculoskeletal problems (eg, joint replacement, fracture, or surgery) within the past year, Parkinson's disease, cerebrovascular accident, or multiple sclerosis were not included in the study. Participants read and signed a voluntary consent form approved by the Institutional Review Board for Human Use at The University of Alabama at Birmingham. Medical information (including the number of falls within the past year and medical history) was elicited verbally from the subjects.

Measurement

A digital stopwatch was used to conduct the timed trials of the balance tests. Subject height and weight were measured by the primary investigator (RCB), as were shoe heel height, shoe sole thickness at the first metatarsal head, and shoe heel width and length. The amount of visible shoe wear was estimated as "none," "minimal," or "badly worn." The Harris test was used to evaluate lower limb dominance.[25]

Procedure

During all tests, subjects were instructed to keep their arms by their sides. If the subjects began to move their arms to regain balance, they were instructed to return them to their sides. The primary investigator demonstrated each test position for the subjects prior to testing. Subjects were given an opportunity to practice each test twice before timed trials began. Subjects who requested help to assume testing positions were permitted to use the investigator's arm to steady themselves prior to starting the timed trials. No instructions were given regarding the subjects' knee position or visual fixation. All testing was performed on level vinyl flooring.

The balance tests performed were the SR and a modified OLST. The SR was performed in a heel-to-toe standing position with the dominant foot behind the nondominant foot. Timing was started after the subjects had assumed the proper position and indicated that they were ready to begin. Timing was stopped if the subjects moved their feet from the proper position, if they opened their eyes on the eyes-closed trials, or if they reached the maximum balance time of 60 seconds. Three trials were performed if the maximum balance time was not reached in either of the first two trials. The longest balance time of the recorded trials was used for the data analysis.

The OLST also was performed in the standing position with the subjects' arms by their sides. Timing was started when the subjects raised the appropriate foot off the ground. Timing was stopped if the subjects displaced the foot they were standing on, touched the suspended foot to the ground, used the suspended foot to support the weight-bearing limb, or reached the maximum balance time of 45 seconds. Three trials were performed if the maximum balance time was not reached in either of the first two trials. The longest balance time of the recorded trials was used for the data analysis.

Most clinicians use a maximum balance time of 30 seconds for the OLST, and we also defined the maximum balance time for the OLST as 30 seconds for the purposes of this study. We continued recording OLST balance time to a maximum of 45 seconds, however, to provide a more accurate statistical calculation of the mean OLST time. By using a 45-second limit for the OLST, we expected that less of a ceiling effect would be observed (in mean balance time calculations) and that a more normal distribution of balance times would be gathered.

The subjects performed each test first with their eyes open and then with their eyes closed. All tests were performed in both the shoes-on and shoes-off conditions. Halfway through the balance testing, a five-minute break was permitted while subjects changed shoes-on–shoes-off conditions. Subjects were permitted to rest between trials or tests as desired. One investigator stood near the subject at all times to prevent falls attributable to loss of balance.

The order of the balance test sequence was random. Four test sequences were possible: 1) SR, right OLST, left OLST; 2) SR, left OLST, right OLST; 3) right OLST, left OLST, SR; and 4) left OLST, right OLST, SR. Each sequence could be performed starting either with or without shoes. Test results were later regrouped and analyzed according to foot dominance instead of right or left OLST conditions.

Two examiners (RCB, SAS) collected data for this study. To examine intertester reliability, these two examiners simultaneously timed one subject, who simulated loss of balance, for 25 trials (for both tests in various conditions). The Pearson product-moment correlation (r) for these 25 paired times was .99.

Data Analysis

Data were analyzed using the statistical analysis system (SAS-PC) computer program.[26] Subjects were stratified by age in five-year increments. We examined balance times and the percentage of subjects reaching maximum balance times within groups by age, number of falls, open-eyes or closed-eyes conditions, and shoes-on or shoes-off conditions. The longest balance time for each condition was used for the data analysis. A two-way analysis of variance (ANOVA) was used to compare the mean balance times of those subjects who had fallen with the mean balance times of all subjects in their age group. A Tukey multiple range test was used separately on each test to evaluate mean balance time versus age.[26] Shoes-on, shoes-off, eyes-open, and eyes-closed relationships to mean balance times were also evaluated by a Tukey multiple range test.

Results

Two of the 73 participants in this study were unable to complete testing because of medical problems and were eliminated from the subject pool: One subject experienced back pain during the SR, and the other subject experienced pain during shoes-off balance testing as a result of a plantar wart. Thus, a total of 71 subjects completed the testing.

The mean age for all subjects was 72.25 years (s = 6.97). Subjects were divided into five groups according to age. The subjects in Group 1 (n = 14) were aged 60 to 64 years ($\bar{X}$ = 62.79, s = 1.31), those in Group 2 (n = 13) were aged 65 to 69 years ($\bar{X}$ = 67.08, s = 1.55), those in Group 3 (n = 16) were aged 70 to 74 years ($\bar{X}$ = 72.00, s = 1.51), those in Group 4 (n = 16) were aged 75 to 79 years ($\bar{X}$ = 77.44, s = 1.26), and those in Group 5 (n = 12) were aged 80 to 86 years ($\bar{X}$ = 82.33, s = 1.87).

Eleven subjects were left-foot dominant. The OLST results were analyzed according to right-leg stance, left-leg stance, dominant-leg stance, and nondominant-leg stance ($p \leq .05$).

Subjects wore a wide variety of shoe styles. Adjusted heel heights (heel height minus sole thickness measured at the first metatarsal head) varied from 0.0 to 5.9 cm. Greater than 90% of the subjects had an adjusted heel height of less than 3.8 cm.

When results of the eyes-open OLST (for all ages) were plotted on a graph, maximal balance times fell into three general clusters. Approximately one half of the subjects had maximal balance times of less than 15 seconds. The remainder of the subjects' maximal balance times on this test fell into two fairly equal groups. The first

Table 1. *Balance Time Means and Standard Deviations (in Seconds) by Age Group Using Best Trial Time of Three Trials*

Group[a]	Test Condition: SR[b]/SO[c]/EO[d]		SR/SO/EC[e]		SR/SF[f]/EO		SR/SF/EC	
	X̄	s	X̄	s	X̄	s	X̄	s
1	56.37	13.59	24.58	20.97	56.41	13.42	39.98	23.31
2	55.93	14.67	31.58	24.82	54.13	16.26	29.86	24.93
3	48.61[g]	19.81	24.19	23.52	49.54	19.67	30.26[g]	24.59
4	39.65[g]	21.80	14.13	14.19	42.96	24.55	13.99[g]	18.56
5	45.49	21.08	21.71	22.12	42.39	26.09	21.66	21.50
All groups	48.94	19.21	22.93	21.41	49.05	20.73	26.98	23.76

Group	Test Condition: D-OLST[h]/SO/EO		D-OLST/SO/EC		D-OLST/SF/EO		D-OLST/SF/EC	
	X̄	s	X̄	s	X̄	s	X̄	s
1	38.48	11.56	5.74	4.21	38.11	12.99	7.73	5.02
2	24.31[g]	16.79	4.27	2.10	28.33	17.89	6.17	4.84
3	18.46[g,i]	14.85	3.68[g]	2.10	20.15[g]	16.00	4.08[g]	2.86
4	10.81[g,i]	11.80	2.34[g]	1.05	9.71[g,i]	10.39	2.82[g,i]	1.21
5	10.65[g,i]	11.33	2.80[g]	1.72	12.33[g,i]	11.50	2.76[g,i]	1.93
All groups	20.43	16.64	3.75	2.68	21.52	17.19	4.68	3.89

Group	Test Condition: N-OLST[j]/SO/EO		N-OLST/SO/EC		N-OLST/SF/EO		N-OLST/SF/EC	
	X̄	s	X̄	s	X̄	s	X̄	s
1	34.13	14.02	8.33	5.89	37.78	13.86	9.90	8.68
2	23.88	18.56	4.49[g]	3.55	25.71[g]	18.56	4.76[g]	3.83
3	19.60[g]	16.61	2.82[g]	1.09	19.84[g]	18.03	3.97[g]	3.33
4	11.97[g]	12.95	3.21[g]	1.76	10.75[g,i]	12.92	2.72[g]	2.05
5	10.17[g,i]	12.23	2.74[g]	1.83	13.02[g,i]	13.87	2.93[g]	1.33
All groups	19.94	16.98	4.29	3.81	21.25	18.06	4.83	5.20

[a]Group 1 (n = 14) = subjects aged 60–64 years; Group 2 (n = 13) = subjects aged 65–69 years; Group 3 (n = 16) = subjects aged 70–74 years; Group 4 (n = 16) = subjects aged 75–79 years; Group 5 (n = 12) = subjects aged 80–86 years.

[b]SR = sharpened Romberg test.

[c]SO = shoes-on test condition.

[d]EO = eyes-open test condition.

[e]EC = eyes-closed test condition.

[f]SF = shoes-off test condition.

[g]Mean balance times are significantly shorter than Group 1 ($p \leq .05$).

[h]D-OLST = one-legged stance test (dominant leg).

[i]Mean balance times are significantly shorter than Group 2 ($p \leq .05$).

[j]N-OLST = one-legged stance test (nondominant leg).

group of balance times was distributed evenly between 15 and 44 seconds, and the second group represented those balance times arbitrarily truncated at the 45-second cutoff time.

Of the 71 participants who completed testing, 19 reported falling at least once within the previous year. One subject had fallen four times, 2 had fallen three times, 5 had fallen twice, and 11 had fallen once. When their mean balance times were compared with the mean balance times of those subjects of the same age group who had not fallen, no statistically significant difference was found between the performance of those who had fallen and those who had not fallen.

The mean balance times for the entire sample and for each of the five age groups are provided in Table 1. For the SR in the eyes-open–shoes-on and eyes-closed–shoes-off test conditions, the mean balance times for subjects in Groups 3 and 4 were significantly shorter than those for subjects in Group 1 ($p \leq .05$); however, no further differences according to age group were observed for the other two conditions of the SR. A Tukey multiple range test revealed that mean balance times for Group 1 were significantly longer than those for

Groups 3, 4, and 5 for all conditions of the OLST ($p \leq .05$).

Table 2 lists the percentages of subjects reaching maximum balance times according to age group and test condition. Twice as many subjects reached maximum balance times on the SR than on the OLST (maximum balance time for the OLST being designated as 30 seconds). For the SR, only the shoes-on–eyes-open test condition showed a significant decrease in balance time according to age group ($p = .013$). Only one subject was able to reach the 30-second maximum balance time in the eyes-closed OLST; therefore, no basis for analysis according to age group existed. All eyes-open OLST results demonstrated a significant decrease in balance time as age increased ($p \leq .008$).

For each of the three tests (SR, dominant-leg OLST, and nondominant-leg OLST) shown in Table 3, the subjects' maximal balance times fell into one of eight balance time performance categories. In the shoes-on–eyes-open test condition, 19 subjects (26.8%) did not reach a maximum balance time on any test (with maximum balance time for the OLST being designated as 30 seconds). Three subjects (4.2%) were able to reach a maximum balance time on the nondominant-leg OLST, but not on the SR or the dominant-leg OLST. A total of 26 subjects (36.6%) reached maximum balance times in the shoes-on–eyes-open test condition. No subjects reached the 30-second maximum balance time in the shoes-on–eyes-closed test condition of the OLST.

Table 3 also demonstrates that more subjects reached the maximum balance time on the SR than on the OLST (with maximum balance time designated as 30 seconds on the OLST). Only 53% of the subjects able to reach the 60-second maximum balance time on an eyes-open SR reached the maximum balance time on any eyes-open OLST. Four subjects (5.6%) were able to reach the 30-second OLST balance time but did not reach the maximum balance time on a SR, as compared with 32.4% and 35.2% of the subjects who reached the maximum SR balance time but did not reach the maximum OLST balance time in the shoes-on–eyes-open and shoes-off–eyes-open conditions, respectively. For eyes-closed test performance, only one subject reached the maximum balance time on the OLST, whereas 34 subjects reached the maximum balance time on the SR.

Using 45 seconds instead of 30 seconds as the cutoff time for the OLST permitted a more accurate estimate of the population mean balance time. If a 30-second OLST cutoff time had been used, mean balance times would have been substantially lower than the mean balance times found in this study. Subjects reached a maximal balance time of 30 seconds during an OLST in 59 trials. Only 76% of those who reached a maximal balance time of 30 seconds, however, were able to reach the 45-second cutoff time. Eyes-closed OLST mean balance times were not affected significantly by the 45-second cutoff time because only one subject was able to reach a 30-second maximal balance time.

Table 4 shows the results of a two-way ANOVA for each test using the shoes-on and shoes-off and the eyes-open and eyes-closed test conditions as factors. The main effects of the eyes-open and eyes-closed test conditions were significant ($p < .0001$ on each test). Subjects maintained their balance longer with their eyes open than with their eyes closed in both the SR and the OLST and in both the shoes-on and shoes-off conditions. No significant interaction was found between the shoes-on and shoes-off and the eyes-open and eyes-closed test conditions, nor were the main effects of the shoes-on and shoes-off test conditions significant.

Discussion

When using a standing test to evaluate balance, the clinician should recognize that performance will differ according to the age of the subject. Potvin and Tourtellotte suggested that the majority of healthy subjects could maintain balance for 30 seconds during the OLST, without reference to age or to eyes-open or eyes-closed conditions.[27] Bohannon et al averaged right-leg and left-leg OLST results of men and women to obtain the following mean balance times according to age (using a shoes-off condition, a maximum balance time of 30 seconds, and the best of five trials): subjects 60 to 69 years of age, eyes-open condition = 22.5 ± 8.6 seconds, eyes-closed condition = 10.2 ± 8.6 seconds; subjects 70 to 79 years of age, eyes-open condition = 14.2 ± 9.3 seconds, eyes-closed condition = 4.3 ± 3.0 seconds.[9]

Bohannon et al's[9] findings are similar to those in this study regarding the OLST. Because we discontinued OLST balance timing at 45 seconds, the mean time could potentially be higher than the 30-second standard time. Only Group 1's mean OLST balance time performance exceeded 30 seconds for the eyes-open condition. When statistically analyzed using the 30-second maximum balance time, mean balance times for the OLST in this study are very close to Bohannon et al's[9] findings.

By using a higher cutoff time and smaller age groupings, the clinician has a more accurate and more realistic value with which to compare his or her findings. The 45-second OLST cutoff time decreased the truncated effect that a 30-second cutoff time would have had on the mean balance time. Although using 45 seconds as the cutoff time provided a better mean balance time calculation, using 30 seconds as a maximum balance time for the OLST in clinical settings still seems appropriate because it can provide an indication of those subjects who exhibit poor balance performance.

Previous research has indicated than an inability to maintain balance for 30 seconds (standing with feet together performing an eyes-open or eyes-closed Romberg test) is an abnormal finding for subjects under 79 years of age.[9,27,28] Bohannon et al's subjects, who ranged in age from 60 to 79 years, were able to perform the Romberg test for 30 seconds (eyes-open

Table 2. *Percentages of Subjects Reaching Maximum Balance Times*

	Test Condition							
	SR[b]/SO[c]/EO[d]		SR/SO/EC[e]		SR/SF[f]/EO		SR/SF/EC	
Group[a]	%	n	%	n	%	n	%	n
1	92.9	13	21.4	3	92.9	13	42.9	6
2	92.3	12	38.5	5	84.6	11	30.8	4
3	62.5	10	18.6	3	68.8	11	37.5	6
4	43.8	7	6.3	1	62.5	10	12.5	2
5	58.3	7	16.7	2	66.7	8	16.7	2
All groups	69.0	49	19.7	14	74.7	53	28.2	20
	$\chi^2 = 12.8$		NS		NS		NS	
	$df = 4$		NS		NS		NS	
	$p = .013$		NS		NS		NS	

	Test Condition							
	D-OLST[g]/SO/EO		D-OLST/SO/EC		D-OLST/SF/EO		D-OLST/SF/EC	
Group	%	n	%	n	%	n	%	n
1	92.9	13	0	0	78.6	11	0	0
2	46.2	6	0	0	53.9	7	0	0
3	18.8	3	0	0	31.3	5	0	0
4	6.3	1	0	0	6.3	1	0	0
5	8.3	1	0	0	8.3	1	0	0
All groups	33.8	24	0	0	35.2	25	0	0
	$\chi^2 = 33.2$		NS		$\chi^2 = 23.3$		NS	
	$df = 4$		NS		$df = 4$		NS	
	$p = .000$		NS		$p = .000$		NS	

	Test Condition							
	N-OLST[h]/SO/EO		N-OLST/SO/EC		N-OLST/SF/EO		N-OLST/SF/EC	
Group	%	n	%	n	%	n	%	n
1	64.3	9	0	0	78.6	11	7.1	1
2	46.2	6	0	0	46.2	6	0	0
3	31.3	5	0	0	31.3	5	0	0
4	12.5	2	0	0	12.5	2	0	0
5	8.3	1	0	0	8.3	1	0	0
All groups	32.4	23	0	0	35.2	25	1.4	1
	$\chi^2 = 13.7$		NS		$\chi^2 = 19.7$		NS	
	$df = 4$		NS		$df = 4$		NS	
	$p = .008$		NS		$p = .001$		NS	

[a]Group 1 (n = 14) = subjects aged 60–64 years; Group 2 (n = 13) = subjects aged 65–69 years; Group 3 (n = 16) = subjects aged 70–74 years; Group 4 (n = 16) = subjects aged 75–79 years; Group 5 (n = 12) = subjects aged 80–86 years.

[b]SR = sharpened Romberg test (maximum balance time = 60 seconds).

[c]SO = shoes-on test condition.

[d]EO = eyes-open test condition.

[e]EC = eyes-closed test condition.

[f]SF = shoes-off test condition.

[g]D-OLST = one-legged stance test (dominant leg) (maximum balance time = 30 seconds).

[h]N-OLST = one-legged stance test (nondominant leg) (maximum balance time = 30 seconds).

Table 3. *Time Performance of Individuals by Test Condition*

Test (sec)			Test Condition							
			SO[d]/EO[e]		SO/EC[f]		SF[g]/EO		SF/EC	
SR[a]	D-OLST[b]	N-OLST[c]	n	%	n	%	n	%	n	%
<60	<30	<30	19	26.8	57	80.3	17	30.0	51	71.8
<60	<30	30	3	4.2	0	0	0	0	0	0
<60	30	<30	0	0	0	0	0	0	0	0
<60	30	30	0	0	0	0	1	1.4	0	0
60	<30	<30	23	32.4	14	19.7	25	35.2	19	26.8
60	<30	30	2	2.8	0	0	4	5.6	1	1.4
60	30	<30	6	8.4	0	0	4	5.6	0	0
60	30	30	18	25.4	0	0	20	28.2	0	0
TOTAL			71	100	71	100	71	100	71	100

Test (sec)			Test Condition							
			SO/EO		SO/EC		SF/EO		SF/EC	
SR	D-OLST	N-OLST	n	%	n	%	n	%	n	%
<60	<45	<45	22	31.0	57	80.3	17	23.9	51	71.8
<60	<45	45	0	0	0	0	1	1.4	0	0
<60	45	<45	0	0	0	0	0	0	0	0
<60	45	45	0	0	0	0	0	0	0	0
60	<45	<45	29	40.9	14	19.7	29	40.9	20	28.2
60	<45	45	4	5.6	0	0	6	8.5	0	0
60	45	<45	4	5.6	0	0	4	5.6	0	0
60	45	45	12	16.9	0	0	14	19.7	0	0
TOTAL			71	100	71	100	71	100	71	100

[a]SR = sharpened Romberg test.

[b]D-OLST = one-legged stance test (dominant leg).

[c]N-OLST = one-legged stance test (nondominant leg).

[d]SO = shoes-on test condition.

[e]EO = eyes-open test condition.

[f]EC = eyes-closed test condition.

[g]SF = shoes-off test condition.

and eyes-closed conditions).[9] The results of our study, however, show that eyes-closed SR performance for individuals under 79 years of age was below 30 seconds for approximately one half of the population.

There are no current studies that compare SR and Romberg test performance. Comparison of the results of subjects performing the Romberg test in Bohannon et al's study[9] and the results of subjects performing the SR in this study does indicate a significant difference between these two tests (the SR appears to be more difficult to perform than the Romberg test).

In earlier studies, subjects' balance times generally decreased as age increased.[9,11] The balance time-age relationship appears most evident for the OLST and to a lesser extent for the SR. The one exception in the present study is Group 4, who performed worse on some tests than Group 5. There are several possible explanations for this finding. Group 5 contained two individuals who excelled on most tests. Using volunteers, as opposed to random selection, may have biased the results. In addition, the health of the individual is generally expected to affect balance time.[29] Although not statistically significant, lower balance performance on certain tests may be linked to the disproportionate number of subjects with musculoskeletal problems in Group 4. Six of the seven women who had musculoskeletal problems within the past five years were in Group 4.

When comparing eyes-open versus eyes-closed test performance in elderly subjects, the findings are quite clear. Eyes-closed performance was markedly worse than eyes-open performance. If visual acuity had been checked and corrected prior to balance testing, there might have been an even greater difference between eyes-open and eyes-closed balance performance.[30] Rosenthall and Rubin[31] and Johnson[32] found a decrease in the number of otoliths and hair cells in the vestibular apparatus, potentially leading to decreased vestibular sensi-

Table 4. *Analysis-of-Variance Summary for Eyes-Open–Eyes-Closed Versus Shoes-On–Shoes-Off Test Conditions Using Sharpened Romberg Test and One-Legged Stance Tests*

Source	df	SS	MS	F	p
Sharpened Romberg Test					
A[a]	1	41004.55	41004.55	90.03	.0001
B[b]	1	307.47	307.47	0.68	.4120
A × B	1	275.50	275.50	0.60	.4374
Error	280	127522.07	455.44		
One-Legged Stance Test (Dominant Leg)					
A	1	19951.10	19951.10	134.24	.0001
B	1	71.94	71.94	0.48	.4872
A × B	1	0.41	0.41	0.00	.9583
Error	280	41614.13	148.62		
One-Legged Stance Test (Nondominant Leg)					
A	1	18261.22	18261.22	111.40	.0001
B	1	61.13	61.13	0.37	.5419
A × B	1	10.71	10.71	0.07	.7984
Error	280	45900.33	163.93		

[a]A = eyes-open–eyes-closed test conditions.

[b]B = shoes-on–shoes-off test conditions.

tivity for the elderly. Decreased levels of peripheral sensation and proprioception are other likely contributors to poor eyes-closed balance maintenance.[13,16,33,34] Perhaps vestibular and sensory loss increased the role that vision plays in balance maintenance among the elderly.

The testing position of the OLST was more difficult to maintain than that of either the SR or the Romberg test. The OLST may be valuable in making fine distinctions in balance performance, such as evaluating the results of treatment used to improve balance. The Romberg test and the SR appear to be best suited for detecting major abnormalities in balance.

A longer maximum balance time could be selected for longitudinal studies, particularly those involving younger subjects, where pretreatment balance times on the OLST approached the 30-second maximum. For example, a person is able to balance 25 seconds before he or she begins an exercise program and is able to balance for 35 seconds after completing the exercise program. Using a maximum balance time greater than 30 seconds would be appropriate for this subject to objectively document the amount of improvement in balance performance.

The SR may not be the test of choice for certain patient populations. Obese subjects with large thigh circumference may not be able to assume the test position. The OLST and the SR place the hip in adduction, which may be contraindicated for subjects who have had a recent total hip replacement.

In this study, three trials were permitted for each test. Bohannon et al[9] and Graybiel and Fregly[11] used up to five trials for the OLST. In the current study, the best trial results were distributed evenly among the three trial sequences except on tests where a large number of subjects reached maximum balance times. When maximum balance times were reached, the majority were on the first trial. Three trials appear to provide a good indication of balance capabilities.

The information concerning falls demands careful analysis. For example, one 63-year-old subject who demonstrated excellent balance performance in this study had fallen four times within the past year; however, she was highly active and participated in more dangerous activities such as mountain hiking and climbing ladders to clear debris off her roof. In contrast, another subject who had fallen was 77 years of age, was moderately obese, had undergone bilateral total knee replacements, and was involved in primarily sedentary activities. The first individual's increased risk of falling was consistent with her greater activity level. The second individual may have been more prone to falls as a result of her medical condition. A more detailed history concerning falls is needed for proper analysis. Evaluating whether falls were due to intrinsic or extrinsic causative factors may help us to recognize a relationship between falls and balance maintenance.

Clinical Implications

Additional research is needed in the area of balance maintenance among the elderly population. Specifically, the OLST may be greatly affected if a subject's hip musculature is weak or easily fatigued. Subjects' balance could be tested prior to and after completion of various exercise programs.

In this study, no significant difference was found between the balance times of those subjects who had fallen within the past year and those who had not fallen. Subjects with serious injuries attributable to falls within the previous year could not participate in this study; therefore, our fall-related results are incomplete. Longitudinal studies are needed to determine whether subjects with poor balance performance have more falls and injuries attributable to falls. A longitudinal study could more specifically evaluate the effect of aging on individual subjects' balance performance.

Foot dominance and shoe wear did not affect balance test results in this population. Thus, the clinician does not need to evaluate foot dominance and could use either the right or left leg for the OLST. Barefoot testing may be preferred because foot abnormalities and ability to stand can be observed more easily than when shoes are worn.

The benefits to the clinician of timed standing balance tests include time efficiency, low cost, no need for special equipment, and the simplicity of training testers. Balance tests are one more tool available to the clinician when trying to determine whether patients are ready to assume more independence in their ADL. They can be used to indicate which patients may require further diagnostic tests. Standing balance tests provide an indication of the patient's ability to maintain balance.

Conclusion

The results of this study indicate that balance times on the OLST and the SR decrease as age increases in noninstitutionalized elderly women. Eyes-closed test performance was markedly worse than eyes-open test performance in the elderly women in this study. More subjects were able to reach maximum balance times on the SR than on the OLST. Of the three tests, the OLST appears to be the most difficult to administer, followed by the SR and then the Romberg test. Foot dominance and shoe wearing did not affect balance performance. Expectations regarding balance maintenance should be adjusted according to age.

References

1 Black FO, Wall C, Nashner LM: Effects of visual and support surface orientation references upon postural control in vestibular deficient subjects. Acta Otolaryngol (Stockh) 95:199–201, 1983

2 Desmedt JE (ed): Advances in Neurology. New York, NY, Raven Press, 1983, vol 39, pp 223, 575–584, 610–618

3 Hooyman N, Cohen HJ: Medical problems associated with aging. Clin Obstet Gynecol 29:361–362, 1986

4 Fansler CL, Poff CL, Shepard KF: Effects of mental practice on balance in elderly women. Phys Ther 65:1332–1338, 1985

5 Fernie BR, Gryfe CK, Holliday PJ, et al: The relationship of postural sway in standing to the incidence of falls in geriatric subjects. Age Ageing 11:11–16, 1982

6 Radebaugh TS, Hadley E, Suzman R (eds): Clinics in Geriatric Medicine. Philadelphia, PA, W B Saunders Co, 1985, vol 1, pp 497–512, 525–536

7 Accident Facts. Chicago, IL, National Safety Council, 1986, pp 2, 15, 17

8 Haga H, Shibata H, Shichita K, et al: Falls in the institutionalized elderly in Japan. Arch Gerontol Geriatr 5:1–9, 1986

9 Bohannon RW, Larkin PA, Cook AC, et al: Decrease in timed balance test scores with aging. Phys Ther 64:1067–1070, 1984

10 Freeman LD: A Descriptive Study of Static and Dynamic Equilibrium of Non-institutionalized Elderly Individuals. Master's Thesis. Birmingham, AL, The University of Alabama at Birmingham, 1984

11 Graybiel A, Fregly AR: A new quantitative ataxia test battery. Acta Otolaryngol (Stockh) 61:292–312, 1966

12 Busse EW: The brain and aging. Clin Obstet Gynecol 29:374–383, 1986

13 Smith B, Sethi P: Aging and the nervous system. Geriatrics 30:109–115, 1975

14 Nagata K, Basugi N, Fukushima T, et al: A quantitative study of physiological cerebral atrophy with aging. Neuroradiology 29:327–332, 1987

15 Gonzalez CF, Lantieri RL, Nathan RJ: The CT scan appearance of the brain in the normal elderly population: A correlative story. Neuroradiology 16:120–122, 1978

16 Wyke B: Cervical articular contributions to posture and gait: Their relation to senile disequilibrium. Age Ageing 8:251–258, 1979

17 Rothschild BM: Age-related changes in skeletal muscle. Geriatric Medicine Today 5:87–95, 1986

18 Aniansson A, Sperling L, Rundgren A, et al: Muscle function in 75-year-old men and women: A longitudinal study. Scand J Rehabil Med [Suppl] 90:92–102, 1983

19 Hasselkus B: Aging and the human nervous system. Am J Occup Ther 28:16–21, 1974

20 Serratrice G, Rouk H, Aquaron R: Proximal muscular weakness in elderly subjects. J Neurol Sci 7:275–299, 1968

21 Olsson JE, Atkins JS: Vestibular disorders. Neurologic Disorders in Otolaryngology 20:83–111, 1987

22 Everitt DE, Avorn J: Drug prescribing for the elderly. Arch Intern Med 146:2393–2396, 1986

23 Dornan J, Fernie GR, Holliday PJ: Visual input: Its importance in the control of postural sway. Arch Phys Med Rehabil 59:586–591, 1978

24 Gabell A, Simons M: Balance coding. Physiotherapy 68:286–288, 1982

25 Harris AJ: Harris Tests of Lateral Dominance. New York, NY, The Psychological Corp, 1958, p 10

26 Statistical Analysis System. Cary, NC, SAS Institute Inc, 1985

27 Potvin AR, Tourtellotte WW: The neurological examination: Advancements in its quantification. Arch Phys Med Rehabil 56:425–437, 1975

28 Dejong RN: The Neurologic Examination, ed. 4. Philadelphia, PA, Harper & Row, Publishers Inc, 1979, p 395

29 Nickens H: Intrinsic factors in falling among the elderly. Arch Intern Med 145:1089–1093, 1985

30 Paulus WM, Straube A, Brandt T: Visual stabilization of posture. Brain 107:1143–1163, 1984

31 Rosenthall U, Rubin W: Degenerative changes in the human vestibular sensory epithelia. Acta Otolaryngol (Stockh) 79:67–80, 1975

32 Johnson L: Degenerative changes and anomalies of the vestibular system in man. Laryngoscope 81:1687–1694, 1971

33 Corso JF: Sensory processes and age effects of normal adults. J Gerontol 26:90–105, 1971

34 Hurwitz LJ, Swallow M: An introduction to the neurology of ageing. Gerontologica Clinica 13:97–113, 1971