Balance and Ankle Range of Motion in Community-Dwelling Women Aged 64 to 87 Years: A Correlational Study

Background and Purpose. This study investigated the relationship between balance measures and ankle range of motion (ROM) in community-dwelling elderly women with no health problems. Identification of modifiable factors associated with balance may enable clinicians to design treatments to help reduce the risk of falls in elderly people. Subjects. The sample consisted of 34 women between the ages of 64 and 87 years ($\overline{X}$=74.7, SD=6.0). Methods. Goniometry was used to determine bilateral ankle active-assistive range of motion (AAROM) and passive range of motion. Balance capabilities were measured with the Functional Reach Test (FRT) and the Tinetti Performance-Oriented Mobility Assessment (POMA). Balance data for the FRT, POMA balance subtest, POMA gait subtest, and POMA total score were correlated with ankle ROM using the Pearson product moment correlation coefficient (PCC). Results. Correlations between ROM and balance scores were found, ranging from .29 to .63. The POMA gait subtest and FRT resulted in higher correlations with ROM than did the POMA balance subtest (left total AAROM PCC=.63, .51, and .31). Correlations using composite ankle ROM scores were higher than individual motions. The strongest correlation existed between bilateral, total ankle AAROM and the POMA gait subtest scores (PCC=.63) Conclusion and Discussion. Correlations exist between ankle ROM and balance in community-dwelling elderly women. Additional research is needed to determine whether treatment directed at increasing ankle ROM can improve balance. [Mecagni C, Smith JP, Roberts KE, O'Sullivan SB. Balance and ankle range of motion in community-dwelling women aged 64 to 87 years: a correlational study. *Phys Ther.* 2000;80:1004–1011.]

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According to Hornbrook et al,[1] fall prevention depends on a clear understanding of the risk factors associated with falls. Falls result from many factors, including both extrinsic or environmental factors and intrinsic factors, such as deficits in sensory, cognitive, central integrative, and musculoskeletal abilities.[2–6] Although some falls may have a single cause, most falls are believed to result from a combination of factors.[7] Not all risks can be eliminated, but Speechley and Tinetti[4] contend that the modification of even one risk factor can be a worthwhile therapeutic goal, even for people with multiple problems.

Among elderly people, decreased force production in the lower extremities has also been identified as a potential risk factor in those who fall when compared with those who do not fall,[8–10] with the greatest compromise in ankle dorsiflexion force.[8] The Frailty and Injuries: Cooperative Studies of Intervention Techniques (FICSIT) trials assessed the effects of interventions in reducing falls among elderly people.[11,12] The exercise interventions incorporated resistance, balance, endurance, and flexibility.[13] Data from trials were analyzed with an individual patient data meta-analysis strategy, planned at the beginning of the FICSIT, combining the evidence from the different trials. Interventions that included flexibility training showed a reduced falls incidence ratio of 0.93.[11] The incidence ratio reflects the relative change in risk to falling in the treatment group.[11] More specifically, decreased ankle range of motion (ROM) may be a risk factor associated with decreased balance.[14–16] A certain amount of ankle ROM

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is needed for functional activities such as walking, which requires a minimum of 10 degrees of dorsiflexion.[17,18]

Range of motion tends to decline throughout the life span due to age-related changes in the mechanical properties and morphology of joint structures (eg, there are decreases in ankle ROM in plantar flexion, dorsiflexion, inversion, and eversion).[19–21] Although elderly men and women without health problems demonstrate large changes in ankle ROM, women show greater age-related declines than men do.[19] We believe that decreased ankle ROM may require altered movement patterns, and these altered movement patterns may compromise balance, thus limiting functional activities such as ambulation. Furthermore, decreases in postural control may result from the use of motions at the hip or trunk that are required to compensate for restrictions in motion at the ankle.[22]

The purpose of this study was to examine the relationship between balance and ankle ROM in community-dwelling, elderly women. These results may serve in clarifying specific components to incorporate into future intervention studies for reducing falls in elderly people.

Method

Subjects
Subjects were recruited from a local senior center through a variety of channels, including the local cable television station, local newspapers, the senior newsletter, posters, fliers, and personal visits to luncheons and activities to describe the purpose of the study. The study design incorporated community service components, including an educational seminar and literature regarding balance, fall prevention, and home safety. Subjects who participated in the study were offered individualized feedback on their scores for balance and ankle ROM, and, if appropriate, simple stretches were demonstrated to improve ankle ROM.

The sample consisted of 34 Caucasian, community-dwelling women with a mean age of 74.7 years (range=64–87). About half of the subjects ranked fall prevention as at least 8 (out of 10) in importance in their daily routine. Twenty-two participants (65%) reported a fall over the past 3 years. Of those who had fallen, 13 participants (59%) reported a single fall caused by a specific event and 9 participants (41%) reported multiple falls.

Instrumentation
The Functional Reach Test (FRT) and the Tinetti Performance-Oriented Mobility Assessment (POMA) were used as measures of balance. The FRT evaluates the maximal distance that a person can reach forward while maintaining a fixed base of support.[23–25] Previous research has established the reliability of measurements obtained with this test from 128 volunteers from 21 to 87 years of age (intraclass correlation coefficient [ICC]=.92).[26] The POMA has 2 subtests. The balance subtest requires an individual to perform balance maneuvers such as sitting, moving from a sitting position to a standing position, standing with eyes closed, and turning 360 degrees. The gait subtest requires an individual to ambulate at a "usual" pace and at a "rapid, but safe" pace. Scores on this assessment categorize individuals as having a "low risk for falling," "greater chance of falling," or "high risk for falling."[23] Tinetti[27] reported agreement on more than 85% of the individual items, with the total score never differing by greater than 10%.

Measurements of dorsiflexion and plantar flexion were obtained with a 360-degree Baseline diagnostic goniometer,* and measurements for eversion and inversion were made with a modified pocket 360-degree goniometer. Both goniometers were calibrated in 1-degree increments.

Reliability
Reliability for the FRT, the POMA, and goniometry was established in a pilot study of 8 subjects. To determine intrarater reliability for the FRT, one tester took 2 measurements (ICC=.96). Interrater reliability for the POMA was determined for 2 testers independently (ICC=.97). Intrarater reliability of goniometric measurements was determined for ROM during the pilot study by taking 2 independent measurements for each motion with the calibrated side of the goniometer shielded from the tester's view (dorsiflexion ICC=.97, plantar-flexion ICC=.99, inversion ICC=.93, and eversion ICC=.94). Goniometric measurements of dorsiflexion, plantar flexion, inversion, and eversion can be reliably determined, with established ICCs of .92, .96, .74, .75, respectively.[28,29]

Procedure
Prior to testing, the purpose and procedures of the study were explained to the subjects. Each subject was asked to read and sign an informed consent form. The tester asked the subject general health questions and administered a foot and ankle examination to determine eligibility. Exclusion criteria were based on a reported history of stroke, vestibular disorders, other neurological problems, uncorrected visual problems, heart attack, uncontrolled hypertension, severe ankle edema, abnormal sensation in lower extremities, foot abnormalities, leg-length discrepancy, or a grade of less than Fair (3) on manual muscle testing of the ankle. Of the 43 women

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* Fabrication Enterprises, Trent Building, S Buckout St, Irvington NY 10533.

who volunteered for the study, 9 were excluded. After testing, general fall-related questions were asked.

The tester then administered the FRT according to the procedure described by the test developers.[26] At a second station, 2 testers assessed bilateral ankle passive range of motion (PROM) and active-assistive range of motion (AAROM). The method used to measure PROM is outlined in *Measurement of Joint Motion: A Guide to Goniometry* by Norkin and White[30] and has been described by previous researchers.[28,29,31] For AAROM, the subject was then asked to actively assist the movement while the tester maintained pressure in the direction of the motion and proper alignment.

The 2-tester procedure included one tester aligning the goniometer according to the bony landmarks specified in Norkin and White's textbook,[30] measuring the beginning and ending positions, and recording the result. The second tester provided stabilization and moved the subject's ankle to the firm end-feel. Dorsiflexion and plantar-flexion measurements were first taken with the subject positioned supine with the knee extended. Dorsiflexion, plantar flexion, eversion, and inversion were measured with the subject's knees flexed and feet unsupported.

At the third station, the POMA was administered by reading instructions from a script. Scores were based on a point system related to normal, adaptive, or abnormal responses.[27] Two testers independently scored the subject's performance on each subtest. The subject was asked to perform the POMA gait subtest twice in order for the testers to change positions for scoring the performance from the side, front, and back of the subject.

Data Analysis

Ankle ROM data were considered in combination similar to the ROM, force, torque, and power scores discussed in previous research.[8,9,32] Four levels, as defined in Figure 1, were considered: (1) unilateral, individual ROM, (2) bilateral, individual ROM, (3) bilateral, planar ROM in the sagittal (dorsiflexion and plantar flexion) and frontal (eversion and inversion) planes, and (4) bilateral, total ankle ROM. Unilateral, total ROM data were also examined. Each of these conditions was correlated with the balance measurement data for the FRT, the POMA balance subtest, the POMA gait subtest, and the POMA total score. The Pearson product moment correlation coefficient (PCC) was used to calculate correlations, using Statistix 1996 software.[†]
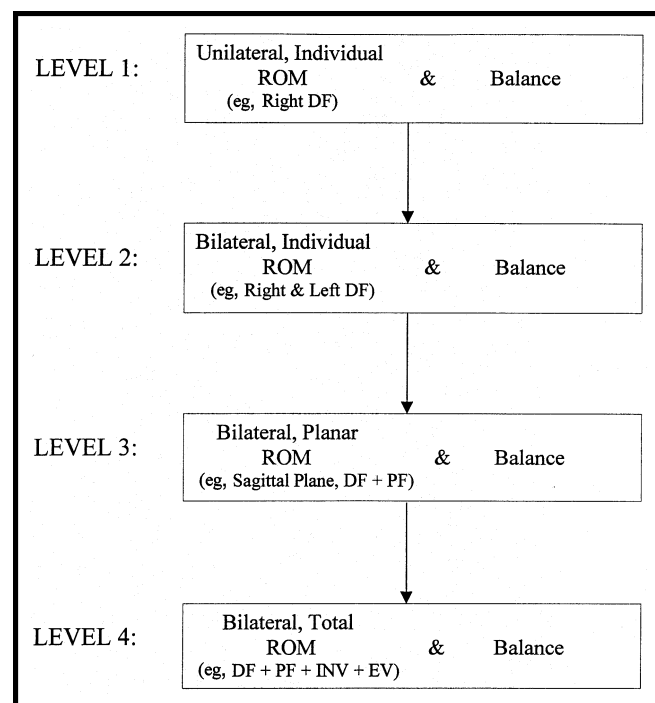
Figure 1.
Levels of correlation based on combinations of range-of-motion data. ROM=range of motion, DF=dorsiflexion, PF=plantar flexion, INV=inversion, EV=eversion.

For a sample size of 34, the minimum level of significance was calculated to be .29 ($P<.01$).[33] Balance is a complex phenomenon, influenced by many factors; therefore, relatively small correlation coefficients may represent statistical significance. Correlation coefficients of .29 and above represent our desired level of probability for this sample size, indicating a relationship on which to base further intervention studies, including balance and ankle ROM.

Results

Functional Reach

The mean FRT score for our sample was 22.1 cm (SD=7.1) (8.7 in [SD=2.8]) (range=9.53–34.93 cm [3.75–13.75 in]), which is within 1 standard deviation of published normative data for women between the ages of 70 and 87 years. Six subjects had an FRT score below 15.2 cm (6 in), which is considered to be indicative of a much greater fall risk.[25]

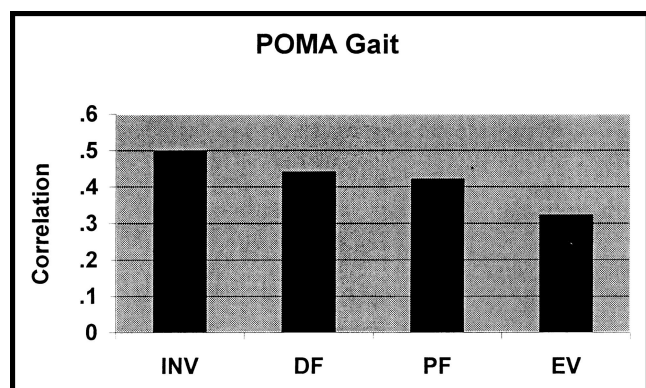### Performance-Oriented Mobility Assessment

The mean POMA score was 22.8/28 (SD=2.5, range=18–27), with a mean on the balance subtest of 12.6/16 (SD=1.7, range=9–15) and a mean on the gait subtest of 10.2/12 (SD=1.1, range=8–12). Two subjects scored below 19, which has been established as "high risk for falling."[34] Twenty-three subjects scored between 19 and 24, which is in the category of "a greater chance of

Table.
Active-Assistive Ankle Range of Motion (in Degrees)

	Knee Flexed (N=34)				Knee Extended (N=34)			
	Left		Right		Left		Right	
	X̄	SE	X̄	SD	X̄	SD	X̄	SD
Dorsiflexion	10.9	3.8	10.9	4.2	8.5	3.1	8.4	3.7
Plantar flexion	63.8	7.7	60.8	8.7	62.1	7.6	60.1	7.7
Inversion	26.1	6.0	29.1	5.5				
Eversion	17.2	4.0	18.2	4.0				

Figure 2.
Pearson product moment correlations between bilateral individual motions and Performance-Oriented Mobility Assessment (POMA)[27] gait subtest scores with knee flexed (*df*=32, N=34). INV=inversion, DF=dorsiflexion, PF=plantar flexion, EV=eversion. (With knee extended, *r* =.40 for DF and *r* =.35 for PF.)
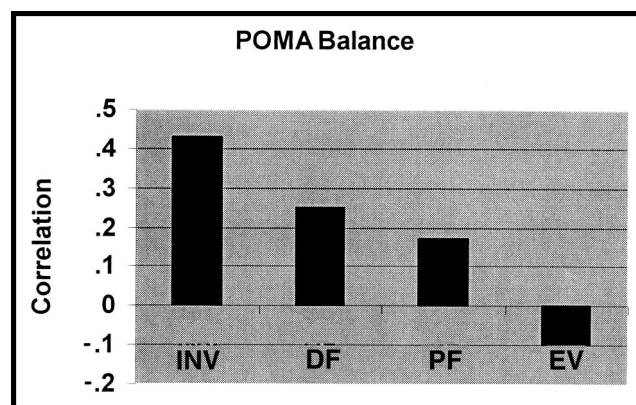
Figure 3.
Pearson product moment correlations between bilateral individual motions and Performance-Oriented Mobility Assessment (POMA)[27] balance subtest scores with knee flexed (*df*=32, N=34). INV=inversion, DF=dorsiflexion, PF=plantar flexion, EV=eversion. (With knee extended, *r* =.37 for DF and *r* =.12 for PF.)

falling."[34] Nine subjects scored over 24 (ie, "low risk for falling"[34]).

Goniometry
The means and standard deviations for each motion are summarized in the Table.

Correlations
Correlations between bilateral, individual AAROM and balance measurements are summarized in Figures 2 through 4. Correlations between balance measurements and AAROM data were generally higher in magnitude than correlations between balance measurements and PROM data, though analogous trends were noted. Correlations were slightly higher for knee-flexed positions than for knee-extended positions. Therefore, AAROM data for the knee-flexed positions were used for further analysis.

Correlations involving the sagittal plane (dorsiflexion and plantar flexion) and the frontal plane (inversion and eversion) resulted in higher correlations with the POMA gait subtest (sagittal-plane PCC=.57, frontal-plane PCC=.56) than with the FRT or POMA balance subtest (level 3 in Figs. 5–7). The highest correlation
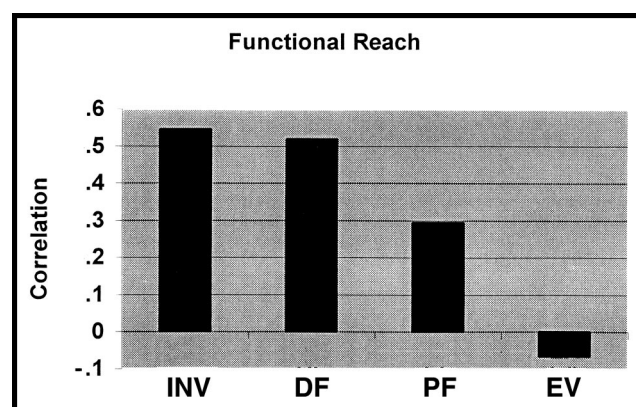
Figure 4.
Pearson product moment correlations between bilateral individual motions and Functional Reach Test[28] scores with knee flexed (*df*=32, N=34). INV=inversion, DF=dorsiflexion, PF=plantar flexion, EV=eversion. (With knee extended, *r* =.47 for DF and *r* =.16 for PF.)
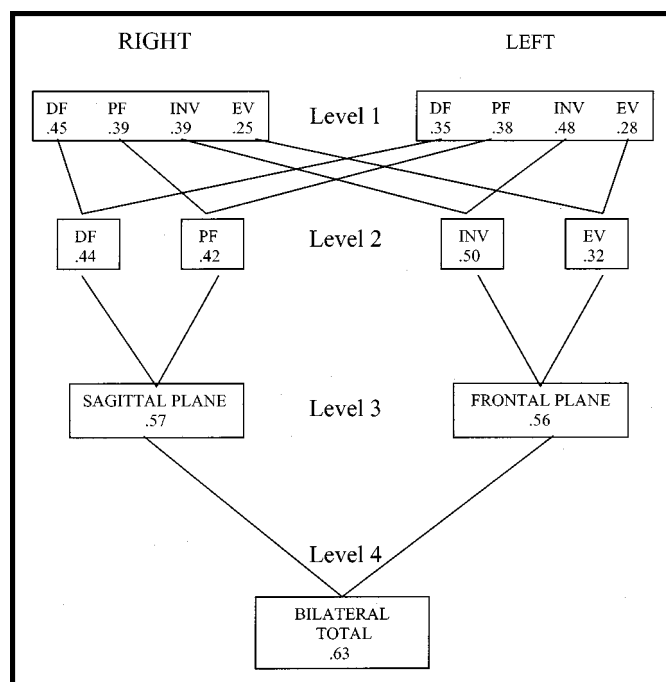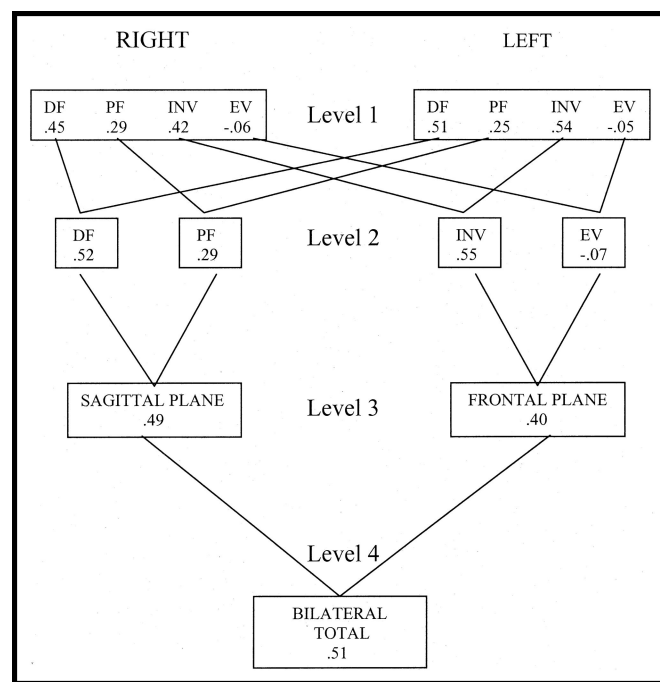
Figure 5.
Pearson product moment correlation values for relationship between Performance-Oriented Mobility Assessment (POMA)[27] gait subtest scores and levels of range-of-motion data (df=32, N=34). INV=inversion, DF=dorsiflexion, PF=plantar flexion, EV=eversion.

Figure 6.
Pearson product moment correlation values for relationship between Functional Reach Test[28] scores and levels of range-of-motion data (df=32, N=34). INV=inversion, DF=dorsiflexion, PF=plantar flexion, EV=eversion.

existed between bilateral total ankle ROM and the POMA gait subtest scores (PCC=.63) (level 4 in Fig. 5).

Discussion

Because there are no normative data for AAROM goniometric measurements for women in this age group, we cannot make comparisons. Our mean values for dorsiflexion, inversion, and eversion fell within 1 standard deviation of values reported by other researchers.[35] We found higher plantar-flexion values than other investigators, which may be attributed to the fact that our measurements were active-assistive, representing the maximal possible range, whereas active motion is dependent on the subject's force-generating capacity.[36] Lifestyle and footwear differences between the populations studied may also have contributed to the difference.

We collected ROM data with the subjects in both knee-flexed and knee-extended positions because we believed that both positions are used in functional situations that challenge balance. Correlations exist between balance measures and ankle ROM in knee-flexed and knee-extended positions, with stronger relationships for the knee-flexed data. If a short gastrocnemius muscle length was the major cause of decreased ankle ROM, we might expect knee-extended positions to produce a higher correlation. This finding may indicate that a short gastrocnemius muscle length may not be the main factor contributing to decreased ankle ROM and to decreases

in our balance measurements. Our data suggest to us that the decreased performance on balance measures associated with restricted ankle motion may be due to noncontractile tissues such as capsule, ligaments, or bone, rather than to a short gastrocnemius muscle length. We believe that future studies should assess the impact of articulatory techniques, such as joint mobilizations, and specific stretching on improvements in ankle ROM and balance. We collected ROM data for both right and left ankles of each subject, although differences in average ROM values between right and left ankles are not thought to exist in elderly individuals.[36]

The importance of specific ankle motions to balance varied with the balance assessment tool. The POMA gait subtest and the FRT resulted in a greater number of correlations with ROM than the POMA balance subtest (Figs. 2–4). These results indicate that ankle ROM may be more associated with balance during ambulation and forward reaching tasks of everyday life than activities performed in the POMA balance subtest. The POMA gait subtest had a moderate correlation with inversion (r=.50) and mild correlations with dorsiflexion (knee flexion: r=.44, knee extension: r=.40), plantar flexion (knee flexion: r=.42, knee extension: r=.35), and eversion (r=.32) (Fig. 3). These results may indicate that all ankle motions contribute to the maintenance of balance during gait.
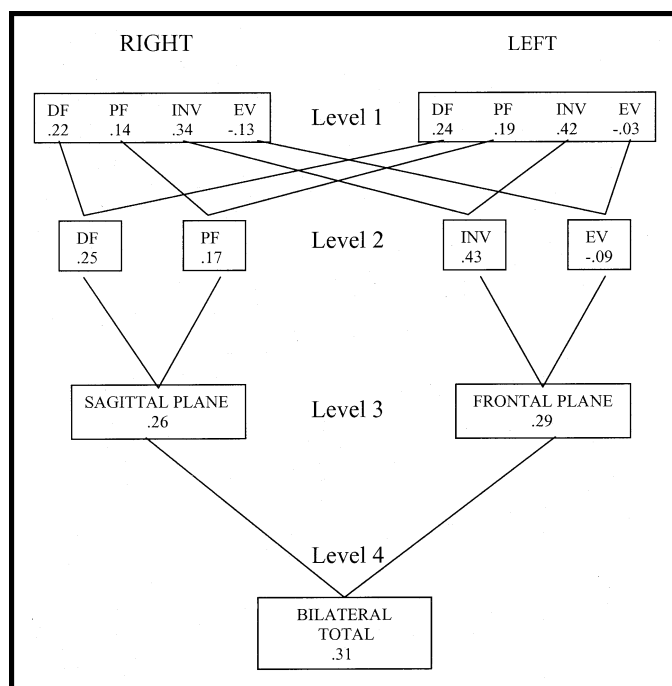
Figure 7.
Pearson product moment correlation values for relationship between Performance-Oriented Mobility Assessment (POMA)[27] balance subtest scores and levels of range-of-motion data (*df*=32, N=34). INV=inversion, DF=dorsiflexion, PF=plantar flexion, EV=eversion.

For each of the balance tests, correlations were calculated at each of 4 levels, as described in the "Data Analysis" section (Fig. 1). For the POMA gait subtest and FRT, higher correlations resulted with each increasing level (Figs. 5 and 6). The POMA balance subtest resulted in lower correlations compared with the POMA gait subtest and the FRT (Fig. 7).

Level 3 ankle ROM data (sagittal- and frontal-plane motions) revealed generally higher correlations with the POMA gait subtest than correlations considering individual motions. These results suggest to us that, although all motions are important, compensation may occur when one motion in a plane is limited, particularly during gait. For example, an individual with a limitation in dorsiflexion may improve in balance performance with an increase in plantar-flexion ROM.

Bilateral, total ankle ROM correlated more strongly with the POMA gait subtest scores than unilateral ROM, suggesting that the impact of 2 restricted ankles on balance will be greater than the impact of only 1 restricted ankle.

The highest correlation in our study existed between bilateral, total ankle AAROM and the POMA gait subtest scores, with a correlation coefficient of .63 (Fig. 5). This result attributes 40% of the variability in balance capabilities to ankle ROM. Bilateral, total AAROM was cor-

related with FRT scores, with a correlation coefficient of .51 (Fig. 6). This result attributes 26% of the variability in balance performance to ankle ROM while forward reaching. The correlation coefficient for the relationship between POMA balance subtest scores and bilateral, total AAROM was .31 (Fig. 7), indicating that ankle ROM may be responsible for 9.6% of the balance capabilities during this test. These results suggest that AAROM of the ankle appears to be an important factor influencing balance during gait.

The low common variance found between ankle ROM measurements and the POMA balance subtest scores indicates to us that ankle ROM may be relatively less important in these activities. During the maneuvers of the POMA balance subtest, including sitting, standing, and standing with eyes closed, other factors may be more critical in influencing balance, but our study was correlational and interventions were outside the scope of this study.

Conclusion
We found that a relationship exists between ankle ROM and performance on balance tests in community-dwelling elderly women with no health problems. Ankle exercises directed at increasing ankle ROM may increase the effectiveness of clinical and community interventions designed for improving balance and reducing falls in elderly women. Our results can provide information to those developing interventions and investigating treatment efficacy because they suggest that interventions for increasing ankle ROM may have an influence on reducing falls in this population.

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