Journal of Gerontology: MEDICAL SCIENCES
1996, Vol. 51A, No. 5, M239–M246

Clinical and Biomechanical Measures of Balance as Fall Predictors in Ambulatory Nursing Home Residents

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Background. We evaluated the capacity of biomechanical and clinical measures of balance to predict future risk of recurrent falls in a cohort of frail, elderly ambulatory residents of 12 Tennessee community nursing homes.

Methods. Baseline measurements of balance and other potential fall risk factors were obtained in 303 ambulatory nursing home residents. Balance measures included biomechanics force platform measurements of postural sway (area ellipse and mean velocity) and clinical measures, which included functional reach, Tinetti balance subscale (adapted from Tinetti's Performance Oriented Mobility Index), timed chair stands, and 10-foot walk. Residents who fell two or more times during follow-up (mean of 11 months) were identified from nursing home incident reports and nursing notes. The predictive value of the balance measures was evaluated by the incidence density ratio (IDR) estimated from proportional hazards models.

Results. There were 118 recurrent fallers (54.2 per 100 person-years). Rates of recurrent falls increased with increasing quintiles of both the biomechanical and clinical measures of balance, with unadjusted IDRs (95% CI) per quintile change of 1.22 (1.07–1.39) for area ellipse, 1.12 (0.98–1.27) for mean velocity of postural sway, 1.29 (1.13–1.47) for the Tinetti balance subscale, 1.24 (1.08–1.41) for timed walk, 1.24 (1.09–1.42) for timed chair stands, and 1.12 (0.98–1.28) for functional reach. Controlling for age, gender, height, and weight did not materially affect the linear relationship between the balance measure quintiles and subsequent recurrent falls. However, after controlling for additional fall risk factors, only area ellipse of postural sway and the Tinetti balance subscale remained independently predictive of subsequent recurrent fall rates, with IDRs of 1.16 (1.02–1.36) and 1.17 (1.01–1.34), respectively. In an analysis where subjects were stratified by tertiles of each of these two measures, each measure appeared to independently predict future rates of recurrent falls. The independent predictive capacity of each measure persisted after controlling for other fall risk factors in a multivariate analysis with IDRs of 1.15 (1.00–1.32) for area ellipse and 1.15 (1.00–1.32) for the Tinetti balance subscale. Inclusion of both balance measures in a model with other fall risk factors to evaluate their relationship did not materially alter IDR point estimates of these risk factors.

Conclusions. In this cohort of frail, nursing home residents, both area ellipse of postural sway and the Tinetti balance subscale independently predicted risk of future recurrent falls. However, the predictive value of other independent fall risk factors on risk of future recurrent falls persisted and was not explained by these two measures. Thus, assessment of patient fall risk based on surrogate endpoints, for either research or clinical practice, may need to include multiple measurements.

FALLS and fall-related injuries and the resulting adverse clinical, social, and economic consequences are a major public health problem in nursing homes. In 1985, there were an estimated 1.3 million residents in a nursing home ⩾ 65 years of age, or 5% of this age group (1). Of these, 45%–70% of residents fall annually (2,3). Because many residents fall multiple times the incidence is 150 falls per 100 person-years (4), at least three times the rate for persons dwelling in the community (5–7). Approximately 11% of nursing home residents incur a serious fall-related injury each year (3,4,8–10). The public health significance of this problem and the growing number of nursing home residents (11) underscore the need to develop and implement preventive programs for this vulnerable population. However, falls research in the nursing home is in its infancy.

An important component of falls research is the development of objective, quantitative measures of balance and mobility. These measures may be used in clinical screening to identify high-risk patients (5,7,12), in epidemiologic studies to elucidate the role of balance impairment in fall risk (6,13,14), in intervention studies to assess the effects of therapy (15), and in pharmacologic studies to determine potential drug effects on postural control (16). Balance and mobility have been measured in the laboratory with biomechanics force platforms (15–21). However, lack of portability has limited their usefulness outside of the laboratory, which has led to development of simple, clinical measures (5–7,12,14,22) to assess balance and mobility in other settings. For community-dwelling elderly, there is a growing body of research concerning the relative performance characteristics of these measures (5,7,13,14,18,23). However, their characteristics in nursing home residents are largely uninvestigated, possibly because of the logistic difficulties of conducting research in this setting. The recent availability of portable biomechanics force platforms enables wider use of this method of balance assessment.

We have previously described the feasibility, reliability, and baseline performance characteristics of biomechanical [postural sway (5,15,24)] and several clinical [balance subscale of Tinetti's Performance Oriented Mobility Index

(22,25), functional reach (14), timed chair stands (5,7), and timed 10-foot walk (26,27)] measures of balance and mobility (referred to as balance measures) in a cohort of 303 ambulatory nursing home residents (28).

The objective of the present study was to evaluate the role of these balance measures in predicting fall risk in the nursing home setting. We addressed three specific questions. First, how well do the proposed balance measures predict fall risk in this frail population? Second, do the measures perform better together in predicting fall risk? Third, what is the relationship between these measures and other known independent fall risk factors?

Methods

Subjects

The study was conducted in 12 Tennessee nursing homes that had participated in a previous study of an educational program designed to reduce nursing home antipsychotic use (29). Eligible residents were those not scheduled to be discharged from the home, able to stand independently without any support for at least 10 seconds, and able to follow simple directions. Residents who were blind, deaf, had loss of lower limb(s), with unstable medical conditions and with end-stage disease were excluded. Of 1,315 residents ≥65 years of age, 955 were ineligible for study measurements, primarily because of inability to stand independently for ≥10 seconds (n = 782). Of the 360 eligible subjects, 303 (84%) agreed to participate, 54 (15.0%) refused, and 3 (0.8%) were excluded because their legal guardians could not be contacted for informed consent (28).

Baseline Data Collection

After preliminary screening of residents for potential eligibility and obtaining informed consent, a trained study nurse and a research assistant evaluated qualifying residents on site, using a battery of pretested instruments. Additional data were also obtained through standardized interview of nursing home care providers familiar with the residents and from facility medical records.

Baseline study measurements were obtained between July of 1991 and January of 1992. Subject follow-up began on the date of assessment and continued for 12 months or until the resident exited from the nursing home (death, discharge, or transfer to another facility); the mean follow-up was 11 months.

Balance measures. — Two categories of balance measures were assessed: biomechanical force platform measurements of postural sway (5,24) and clinical measures, which included the balance subscale of Tinetti's Performance Oriented Mobility Index (22,25), functional reach (13,14), timed chair stands (5,7), and timed 10-foot walk (28). These measures were selected because they are correlated with falls in community-dwelling elderly (5–7,12,13), simple to administer, suitable for frail, elderly subjects, and commonly used. In the present study, these measures had good to adequate test-retest reliability with intraclass correlation coefficients of 0.72 for area ellipse of postural sway, 0.98 for the Tinetti's balance subscale, 0.57 for functional reach, 0.63 for timed chair stands, and 0.88 for the timed walk (28).

Postural sway. — Postural sway is the corrective body movement resulting from the control of body position. It usually is measured during quiet, upright standing and thus reflects the body's effort at maintaining balance in that posture, with increased sway indicating greater effort and thus poorer balance. We used a portable biomechanics force platform (Model OR6-5 Force Torque Dynamometer, Advanced Mechanical Technology, Inc., Newton, MA) that consists of a rigid metal plate (18.25 × 20 inches wide and 3 inches in height) supported by 4 strain-gauge force transducers, and related hardware and software for data acquisition and analysis. The force and moments of force were acquired at a sampling frequency of 50 cycles per second for a duration of 10 seconds per reading. The data were then electronically filtered, digitized, and stored in an IBM-compatible personal computer (Toshiba T3200 SX) to compute the coordinates of the center of pressure.

Measurements were obtained from four stances of increasing difficulty: the double stance–eyes open (DSEO), double stance–eyes closed (DSEC), feet together–eyes open (FTEO), and feet together–eyes closed (FTEC). In each stance, the subject was asked to stand still on the platform and look straight ahead at a black spot on a wall about 10 feet away for at least 10 seconds. Three readings, each lasting 10 seconds, were taken for each stance, and the means of these readings were used in the analysis.

Postural sway was evaluated by the center of pressure (COP) excursions which reflect the shifts in the forces applied on the platform by the body in its effort to maintain its upright posture. COP excursions have been characterized in several ways (17,30,31), including the area covered by the excursions and the speed of movement of the COP during the trial. We evaluated several measures of sway generated by the force platform software, including area ellipse, area of COP excursions, radial distance and the standard deviation of the radial distance of the COP, anteroposterior and lateral distances traveled by the COP, and the associated standard deviations and mean velocity. Because of the extremely high correlations (r's ranging from .72 to .99) between the different measures, for the present analysis, we chose the area ellipse (sq. cm.) and the mean velocity (cm/second) of the COP excursions. The area ellipse is the 95% confidence ellipse for the mean of the COP coordinates (31). It has been shown to provide a better approximation of the area covered by the COP excursions than previously used area measures of sway (31). The rationale for using an area measure to quantify sway is that it represents the portion of the base of support utilized during quiet stance (31). The mean velocity is related to the frequency of the COP excursions, and thus may quantify a different component of sway than the elliptical area. It was obtained as the mean over 10 seconds of instantaneous velocity, measured as the COP displacement between each sampling point divided by the sampling interval (.02 seconds). Higher values of either measure indicate increased sway or poorer balance control.

Tinetti balance subscale. — We selected six items (sitting down on a chair, sitting balance, rising up from a chair, immediate standing, standing with feet together for 10 seconds, and standing with feet at semi-tandem for 10 seconds) from the balance subscale of the Tinetti Performance Oriented Mobility Index (22). A study nurse scored performance in each item from 0 (unable, impaired performance) to 2 (normal, maximal performance). Individual item scores were summed to obtain the total score (0–12), with higher scores indicating better balance. We did not assess other items (e.g., sternal nudge, tandem stand, and standing on one leg) of the original scale because subjects in pilot testing found these maneuvers stressful and often were unable to complete them.

Functional reach (FR). — We used the "yardstick method" described by Duncan and colleagues (14) to measure FR, defined as the maximal distance one can reach forward beyond arm's length while maintaining a fixed base of support in the standing position. A total of three trials were recorded. If a subject touched the wall or took a step during the test, the procedure was repeated. To minimize impact of possible measurement errors within the three readings, we discarded any reading (7 subjects) more than 2.5 standard deviations from the mean, and the means of the two remaining readings were included in the analysis. Higher values of FR indicate better balance. Subjects who were unable to perform the functional reach were so coded.

Timed chair stands. — Subjects were asked to sit on a thinly padded, armless chair, and instructed to rise up to a full standing position and then sit down on the chair, three times. The time taken to complete the three chair stands was recorded. However, if the time taken exceeded 30 seconds, then the number of stands completed within 30 seconds was recorded. The mean time per chair stand was calculated; higher times indicated poorer performance. Subjects unable to get up by themselves were coded as having tried but unable.

Timed walk. — Subjects were asked to walk at their normal pace with their usual walking aids, if any, on a marked 10-foot walkway, with bare or thinly carpeted floor, in a hallway or suitable room, twice. The time and number of steps taken by subjects to walk the course was measured, and the mean time in seconds taken to walk 10 feet was calculated. A higher value indicated poorer performance.

Other fall risk factors. — We measured several other potential risk factors for falls at baseline with standard instruments. Cognitive impairment at baseline was assessed with the Folstein's Mini-Mental State Examination [MMSE; (32)], behavior problems by the Nursing Home Behavior Problem Scale [NHBPS; (33) rated by facility care providers familiar with the resident], and depressive symptoms by the 15-item Geriatric Depression Scale [GDS; (34)]. Number of dependencies in activities of daily living was assessed by Lawton's Physical Self-maintenance Scale (completed by a facility nurse familiar with the residents) (35). Psychotropic drug use (antipsychotics, benzodiazepines, cyclic and atypical [trazodone] antidepressants, and non-benzodiazepine hypnotics/anxiolytics), defined as use for at least 4 days of the week preceding assessment, was abstracted from the nursing home medication administration records (MAR). Blood pressure readings were obtained with a portable mercury sphygmomanometer after 5 minutes resting in the supine position and at one minute on standing, respectively; orthostatic hypotension was defined as a drop in systolic pressure of ⩾20 mmHg. Upper extremity weakness was defined as limitation of range of motion/weakness of the shoulder or grip weakness, as determined by manual muscle testing. Similarly, lower extremity weakness was defined as limitation of range of motion/weakness of the hip or knee. Corrected near vision was measured using the Rosenbaum pocket screener and recorded as a Jaegar score; severe impairment was defined as scores of 16 or greater (36). Hearing was assessed with the "whisper test"; impairment was defined as inability to repeat the whispered words for both ears (36). The study team also ascertained height and weight to calculate the body mass index (BMI) and current use of any assistive devices for ambulation.

Falls

The study outcome was the occurrence of two or more falls during the follow-up period. This outcome has been studied frequently in nursing homes and other high-risk populations because it identifies regular fallers at highest risk of injury and eliminates occasional, circumstantial falls (7,25,37). A fall was defined as an unintentional change in position resulting in coming to rest on the ground or other lower level (38). Because reliable data on fall circumstances were unavailable, we included all falls in the present analysis, including the small number possibly resulting from extrinsic factors and acute disease processes, such as stroke, seizures, and myocardial infarction. Trained nurse abstractors ascertained falls from review of nursing home incident reports and the nursing home chart (primarily nursing notes but also hospitalization and emergency room visit discharge summaries, radiological reports, and physician notes) for the period from 90 days preceding the assessment date through the end of follow-up. In the analysis, the event date was that of the second fall.

Statistical Analysis

In the present analyses, subgroups of residents were defined by quintiles of the scores for the balance variables. Residents attempting but unable to perform a balance maneuver were classified into the highest quantile (i.e., most impaired) of that measure. The predictive value of the balance measures (i.e., association between performance quintile in the balance measure at baseline and subsequent rate of recurrent falls) was evaluated by the incidence density ratio (IDR), defined as the ratio between two average rates, and similar to a relative risk (39–41). Univariate and multivariate IDRs were estimated from proportional hazards models (39,42), an appropriate statistical technique for analysis of cohort data with variable follow-up (39,40). The quintiles of the balance measures were treated as continuous variables in the models to estimate change in the rate of recurrent falls per unit quintile. Several models were used to evaluate the predictive performance of each balance measure: a univariate model, a second model adjusting for age and gender, a third model further adjusting for height and weight, and a fourth a priori model, further adjusting for other fall risk factors previously identified in this cohort (43), which included assistance needed with number of activities of daily living, tertiles of behavior problems, fall in 90 days preceding assessment date, and use of psychotropic drugs. A *p*-value (two-sided) of <.05 was used to indicate statistical significance. All analyses were carried out with the SAS-PC statistical software package.

Results

Cohort members were typically very old (mean age 81 ± 7.5 years), mostly White (95%), female (72%), had high levels of cognitive impairment (mean MMSE = 16), and depressive symptoms (mean GDS = 10.4). Physically, the subjects were frail, with 93% needing assistance with at least one activity of daily living, 17% with upper and 33% with lower extremity weakness, 31% with significant hearing difficulty, and 30% with extremely poor corrected near vision (Jaegar score of 16 or more) (28). Sixty-three percent of the subjects were regular users of one or more psychotropic drugs (antipsychotics 17%, benzodiazepines 16%, cyclic antidepressants 7%, other sedatives 7%, and multiple 17%). During the study follow-up period, 118 residents fell two or more times, a recurrent fall rate of 54.2 per 100 person-years.

Of the four stances studied, the double stance–eyes open had the strongest linear relationship between quintiles of sway area ellipse and subsequent rates of recurrent falls (Figure 1). Recurrent fall rates of area ellipse in this stance ranged from 36.1 in the lowest quintile to 84.9 per 100 person-years in the highest. For each quintile increase in area ellipse, there was a 22% increase in the rate of recurrent falls (IDR [95% CI] = 1.22 [1.07–1.39]). All study subjects were able to complete measurements for this stance. Area ellipse in the double stance–eyes closed stance also showed a linear relation with fall risk; however, the magnitude of trend was slightly lower and 19% of subjects could not complete

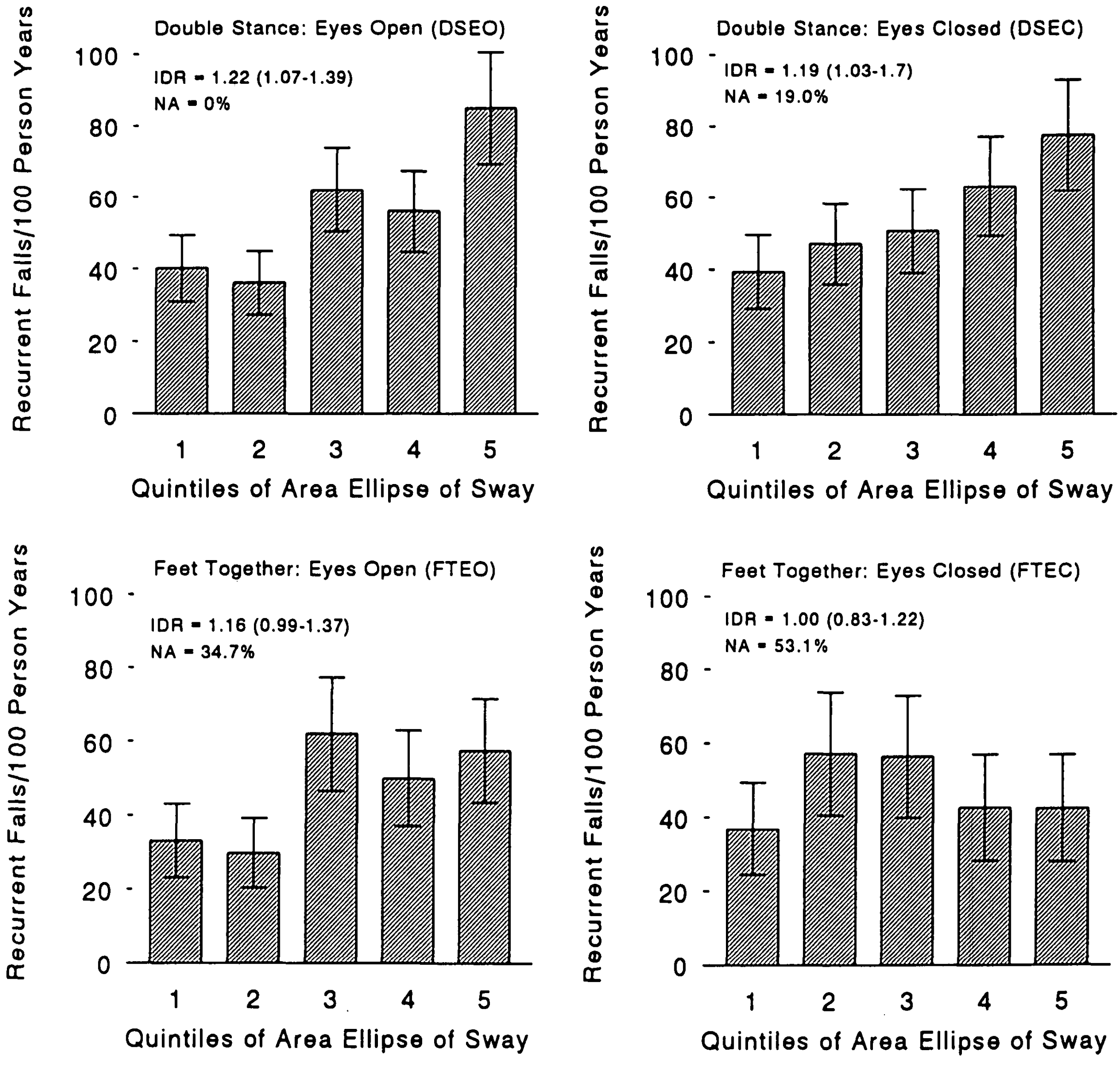

Figure 1. Recurrent fall rates per 100 person-years and unadjusted incidence density ratios (IDR, 95% confidence intervals) by quintiles of area ellipse of postural sway, by stance (NA = percent subjects not completing test). The IDR represents the estimated increase in recurrent fall risk for a one-quintile increase in the balance measure, assuming a linear relationship.

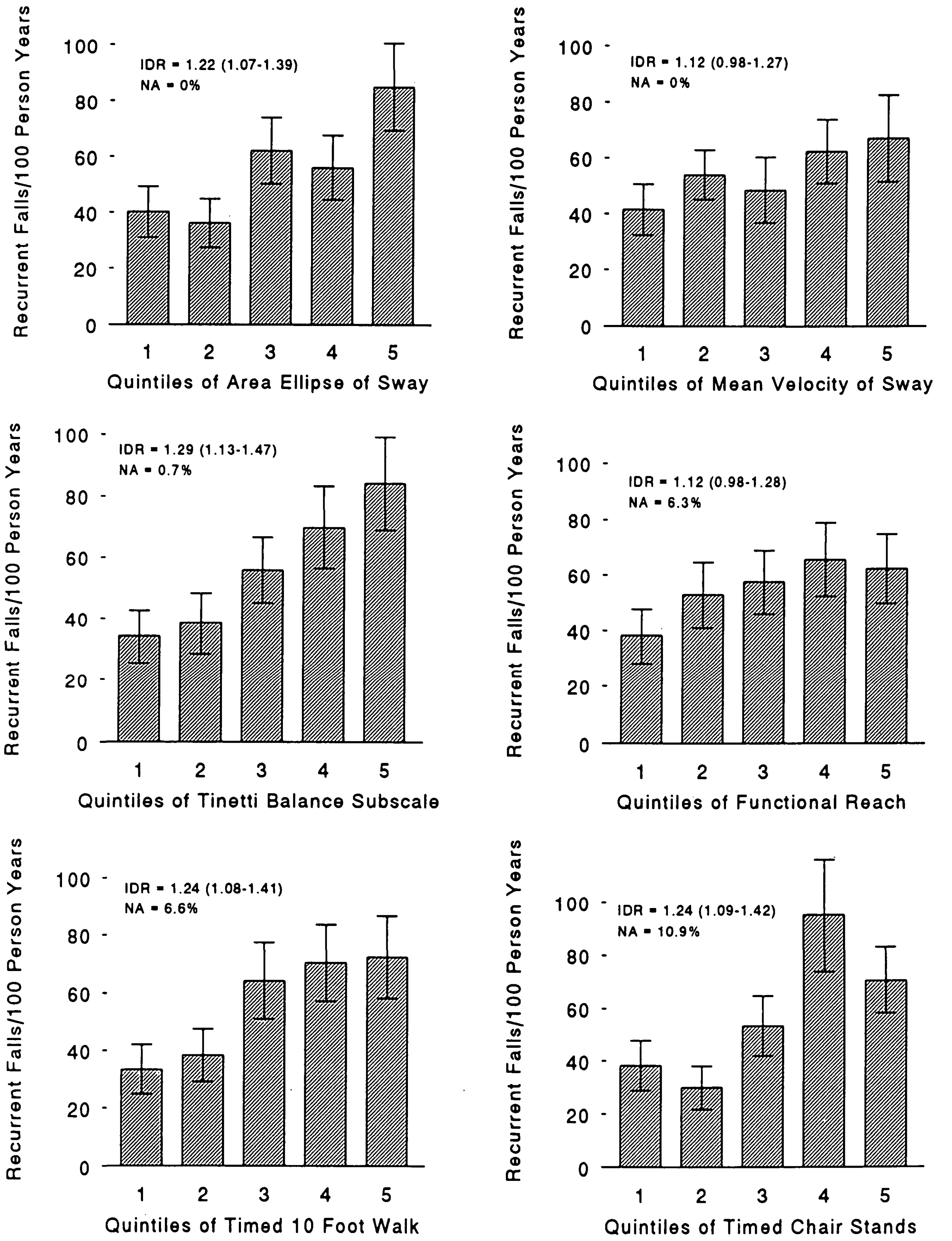

Figure 2. Recurrent fall rates per 100 person-years and unadjusted incidence density ratios (IDR, 95% confidence intervals) by quintiles of balance measures (NA = percent subjects not completing test). The IDR represents the estimated increase in recurrent fall risk for a one-quintile increase in the balance measure, assuming a linear relationship.

the test with this stance. The other two stances were less predictive of fall rates and had increasing proportions of residents unable to complete the test (Figure 1).

There was a general trend toward increased recurrent fall rates with increasing quintiles of both the biomechanical and clinical measures of balance (Figure 2). For the biomechanical measures, the estimated linear trend was more pronounced for the area ellipse (IDR = 1.22 [1.07–1.39]) than for the mean velocity (IDR = 1.12 [0.98–1.27]). Of the clinical measures, the Tinetti balance subscale was the best predictor of subsequent rates of recurrent falls (IDR = 1.29 [1.13–1.47]), followed by timed walk (IDR = 1.24 [1.08–1.41]), timed chair stands (IDR = 1.24 [1.09–1.42]), and functional reach (IDR = 1.12 [0.98–1.28]).

We evaluated the extent to which the predictive value of the biomechanical and clinical measures was affected by control for demographic and anthropometric characteristics and by control for other significant fall risk factors (Table 1). Controlling for age, gender, height, and weight did not materially affect the linear relationship between the balance measure quintiles and subsequent recurrent falls. However, after controlling for additional fall risk factors (activities of daily living, behavior problems, fall in 90 days preceding assessment, and baseline use of psychotropic drugs), area ellipse of postural sway and the Tinetti balance subscale were the only two measures that remained independently predictive of fall rates with IDRs of 1.16 (95% CI 1.02–1.36) and 1.17 (95% CI 1.01–1.34), respectively (Table 1).

The previously reported low correlation between area ellipse and the Tinetti balance subscale (Pearson r = .28) indicated these measures may assess different components of balance (28). Thus, we evaluated the joint capacity of these measures to predict recurrent fall rates (Figure 3). Because of small numbers, subjects were stratified by tertiles of each measure. This analysis indicated that each measure independently predicted future rates of recurrent falls (Figure 3). The independent predictive capacity of each measure persisted after controlling for other fall risk factors in a multivariate analysis (Table 2). In this analysis, the IDR for a one quintile increase in area ellipse and Tinetti balance subscale were 1.15 (95% CI 1.00–1.32) and 1.15 (95% CI 1.00–1.32), respectively.

To evaluate the extent to which these two balance measures explained the effects of other independent fall risk factors, we fit a model which included other fall risk factors. Inclusion of the balance measures did not materially alter the point estimates of the IDRs for the other fall risk factors (Table 2).

Discussion

Biomechanical and clinical measures of balance independently predict future fall risk in community-dwelling elderly (5–7,12,13,24,44,45). Our data suggest that these measures also predict risk of recurrent falls in ambulatory nursing home residents, but with some important differences.

Because of higher prevalence of physical frailty in nursing home residents, test procedures may need to be modified. In community-dwelling elderly, the more challenging stances in force platform measures of postural sway (e.g., standing on one leg with eyes open) are thought to provide better prediction of fall risk (18). However, in the nursing home population subjects had difficulty completing the more challenging stances, with fewer than 50% completing the test in the most challenging stance (feet together–eyes closed). Furthermore, some of the more challenging stances actually had less predictive value than DSEO. Similarly, the Tinetti's Performance Oriented Mobility Index was modified to exclude the more challenging maneuvers, such as standing on one leg and sternal nudge, which we judged to be too risky and stressful in pretesting. Despite its potential appeal as a simple clinical measure of balance, many residents had difficulty in completing the functional reach measurements, possibly explaining its poor predictive value in this population.

In this frail population, the Tinetti balance subscale and area ellipse of postural sway were the best predictors of future rates of recurrent falls. There was a more than twofold increase in recurrent fall rates between the lowest and the highest quintile of each of these measures. The increase in fall rates persisted in all the models, including the one with adjustment for other fall risk factors. Inspection of the data suggests the Tinetti balance subscale was the best single predictor of future recurrent fall rates, with the most linear relationship and greatest high:low quintile ratio.

It is possible that the different components of balance measured by postural sway (static balance) and the Tinetti balance (primarily dynamic balance) may independently

Table 1. Rate of Recurrent Falls and Incidence Density Ratio (IDR) by Quintiles of Balance Measures*

	Model 1†			Model 2†			Model 3†			Model 4†		
Balance Measure	IDR‡	95% CI	p-value	IDR‡	95% CI	p-value	IDR‡	95% CI	p-value	IDR‡	95% CI	p-value
Area ellipse	1.22	1.07–1.39	.003	1.22	1.07–1.40	.004	1.25	1.09–1.44	.002	1.16	1.02–1.36	.03
Mean velocity	1.12	0.98–1.27	.10	1.10	0.96–1.26	.18	1.11	0.97–1.27	.13	1.08	0.95–1.24	.24
Tinetti balance subscale	1.29	1.13–1.47	.0002	1.27	1.11–1.45	.0005	1.26	1.10–1.45	.0007	1.17	1.01–1.34	.04
Functional reach	1.12	0.98–1.28	.10	1.10	0.96–1.26	.17	1.10	0.95–1.26	.20	0.98	0.84–1.14	.83
Timed chair stands	1.24	1.09–1.42	.001	1.23	1.08–1.41	.003	1.21	1.06–1.40	.009	1.20	0.99–1.47	.07
Timed walk	1.24	1.08–1.41	.002	1.22	1.06–1.41	.005	1.22	1.06–1.40	.007	1.13	0.96–1.32	.15

*Subjects were categorized by quintiles of balance measures, with 1 denoting the lowest quintile and 5 the highest.

†Incidence density ratios (IDR) were calculated in 4 models: Model 1 calculated the crude IDR, model 2 adjusted for age and gender, model 3 adjusted for age, gender, and height and weight, and model 4 included terms in model 3 and in addition, terms for behavior problems, activities of daily living, history of falls, and use of psychotropic drugs.

‡The IDR represents the estimated increase in recurrent fall risk for a one-quintile increase in the balance measure, assuming a linear relationship.

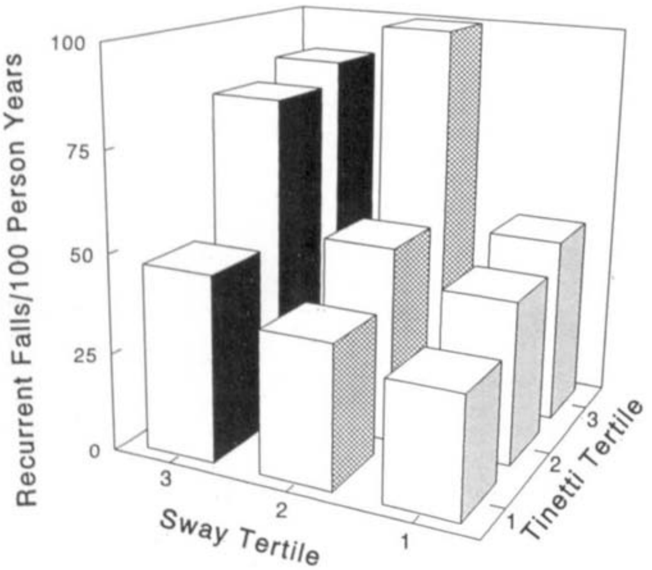

Figure 3. Recurrent fall rates per 100 person-years stratified by tertiles of area ellipse of postural sway and Tinetti balance subscale.

Table 2. Adjusted Incidence Density Ratios (IDR)* of Recurrent Falls, by Resident Characteristics Independently Associated with Fall Risk†

	Balance Measures Included in the Model?			
	No		Yes	
Variable	IDR	95% CI	IDR	95% CI
Age, years				
<75	1.00	—	1.00	—
≥75	1.64	1.00–2.68	1.60	0.98–2.64
Assisted activities of daily living				
0–1	1.00	—	1.00	—
2–3	1.66	0.94–2.93	1.57	0.89–2.78
≥4	2.88	1.61–5.16	2.41	1.33–4.37
Fall in 90 days preceding assessment				
No	1.00	—	1.00	—
Yes	2.00	1.33–2.98	1.76	1.17–2.65
Behavior problems (NHBPS)				
0.0–4.2	1.00	—	1.00	—
4.2–10.3	0.96	0.59–1.57	0.93	0.54–1.48
>10.3	1.56	1.01–2.41	1.63	0.99–2.37
Psychotropic drug use, any				
No	1.00	—	1.00	—
Yes	1.57	1.06–2.33	1.72	1.15–2.58
Tinetti balance subscale quintile	—	—	1.15	1.00–1.32
Area ellipse quintile	—	—	1.15	1.00–1.32

*The incidence density ratio of recurrent falls associated with each variable was adjusted for all the other variables.

†The present IDRs differ from those reported in the previous study (39) for several reasons. The present analysis includes 21 occasional users of psychotropic drugs, who were excluded from the prior study. The present model, unlike that for the previous study, includes terms for "fall in 90 days preceding assessment," but excludes cognitive status. In the present analysis, the psychotropic drug user category includes occasional users.

contribute to risk of falls (23,28). Our data are consistent with this hypothesis. We found area ellipse and the Tinetti balance subscale each independently predicted future rates of recurrent falls in a model which included both measures. An analysis stratified by tertiles of each measure also suggested each of the two measures independently predicted future fall risk, with the highest risk group subjects in the upper tertiles of each measure. However, our sample size was marginally adequate for study of this question. Further studies are needed to better evaluate the joint predictive capacity of these measures.

An ideal global surrogate measure for fall risk would integrate the effects of the multiple factors that mediate postural control. However, consistent with other fall studies (5–7,12,13,24,44,45), our data suggest that balance measures are not such global surrogate measures and that other factors play an important role in postural control. Indeed, the point estimates of other risk factors for recurrent falls were little altered by inclusion of the balance measures in the model. This suggests the complexity of fall etiology and reinforces the need for multifactorial prevention strategies (46–48). In conclusion, there may be no single measurement that is a surrogate for fall risk in frail nursing home residents. Assessment of patient fall risk based on surrogate endpoints, for either research or clinical practice, thus may need to include a multiple of measurements.

Acknowledgments

This study was supported in part by grants from the Centers for Disease Control, Atlanta (R49/CCR407306-02), and the John A. Hartford Foundation, New York, NY (89308-G), and by a cooperative agreement (FD-U-000073-08) with the Food and Drug Administration, Bethesda, MD. Dr. Thapa received support from a CIBA-GEIGY fellowship in Pharmacoepidemiology award.

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Received March 21, 1995
Accepted October 2, 1995