Research Report

Predicting the Probability for Falls in Community-Dwelling Older Adults

Background and Purpose. The objective of this retrospective case-control study was to develop a model for predicting the likelihood of falls among community-dwelling older adults. **Subjects.** Forty-four community-dwelling adults (≥65 years of age) with and without a history of falls participated. **Methods.** Subjects completed a health status questionnaire and underwent a clinical evaluation of balance and mobility function. Variables that differed between fallers and nonfallers were identified, using *t* tests and cross tabulation with chi-square tests. A forward stepwise regression analysis was carried out to identify a combination of variables that effectively predicted fall status. **Results.** Five variables were found to be associated with fall history. These variables were analyzed using logistic regression. The final model combined the score on the Berg Balance Scale with a self-reported history of imbalance to predict fall risk. Sensitivity was 91%, and specificity was 82%. **Conclusion and Discussion.** A simple predictive model based on two risk factors can be used by physical therapists to quantify fall risk in community-dwelling older adults. Identification of patients with a high fall risk can lead to an appropriate referral into a fall prevention program. In addition, fall risk can be used to calculate change resulting from intervention. [Shumway-Cook A, Baldwin M, Polissar NL, Gruber W. Predicting the probability for falls in community-dwelling older adults. *Phys Ther.* 1997;77:812–819.]

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Identification of older adults who are at a risk for falling is a vital medical concern. Although falls represent a health hazard to many older adults, there is mounting evidence that suggests that frequency of falls can be reduced through interventions designed to influence factors contributing to increased fall risk among older adults.[1–6]

Approximately 25% to 35% of people over the age of 65 years experience one or more falls each year.[7–9] The consequences of falls among older adults are often devastating. Among people over the age of 65 years, fall-related injuries are the leading cause of death from injury.[10,11] Forty percent of hospital admissions among people over the age of 65 years are reported to be the result of fall-related injuries, resulting in an average length of stay of 11.6 days.[12] Approximately one half of older adults hospitalized for fall-related injuries are discharged to nursing homes.[12] Falls that do not lead to injury often begin a downward spiral of fear that leads to inactivity and decreased strength, agility, and balance and that often results in loss of independence in normal activities of self-care.[4,9,13–15]

Numerous studies[2,4,9,16–20] have investigated the most likely cause or causes of falls, with varying results. Risk factors for falls have been classified as intrinsic (those related to the individual) and extrinsic (those associated with environmental features). Among the intrinsic factors, researchers[2,4,16–18] have identified decreased balance and mobility skills as very strong predictors of the likelihood for falls. Other researchers focusing on intrinsic factors have identified decreased functional skills such as moving from a sitting position to a standing position,[2,19,20] the inability to reach forward in the standing position,[18] the inability to bend over and pick up something from the ground,[4] the inability to descend stairs step over step without using a handrail,[2] and the inability to tandem walk to be important predictors of falls.[2] Lower-extremity weakness has also been reported as an important intrinsic factor found among older adults who have fallen.[3,16,17] Other intrinsic factors, including decreased vibratory sensation in the feet,[20] reduced cognitive function,[16] and prior fall history,[16,21] have also been described as predictors of falls among older adults.

An increased understanding regarding the factors contributing to falls among older adults has led to the development of a variety of fall prevention programs. The goal of fall prevention programs is to modify risk factors and thereby reduce the likelihood for future falls

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in older adults who are determined to be at high risk. For example, patients with impaired balance and mobility skills can reduce their risk for falls through appropriate exercise.[6,22,23]

A valid and reliable clinical assessment method that identifies relative risk for falls is needed for identifying those individuals who would be appropriate for referral into a fall prevention program. In addition, measures that quantify the risk of falling can potentially be used as a standard for evaluating outcomes following intervention. Thus, the purpose of this research was to develop a model to quantify fall risk among community-dwelling older adults.

Method

Subjects

The first 44 volunteers who met the study criteria were selected from among those people responding to an advertisement in a local newspaper and at local senior centers. Criteria for inclusion in the study were (1) age 65 years or older, (2) living independently in the community, (3) no neurological or musculoskeletal diagnosis that could account for possible imbalance and falls, such as a history of cerebrovascular accident, Parkinson's disease, cardiac problems, transient ischemic attacks, or lower-extremity joint replacements. Subjects were excluded if they reported serious visual or somatosensory impairments.

Subjects were classified as fallers or nonfallers. The criterion for inclusion in the faller category was a self-report of two or more falls within the 6 months prior to the study. A *fall* was defined as any event that led to an unplanned, unexpected contact with a supporting surface. We excluded falls resulting from unavoidable environmental hazards such as a chair collapsing. In addition, we excluded people who had only 1 fall within 6 months, in order to maximize the possibility of selecting a sample of older adults with recurrent falling problems. Twenty-two older adults were classified as fallers, and 22 adults were classified as nonfallers.

Procedure

After giving informed consent, all subjects completed a health status questionnaire, providing information on age, residential status, marital status, medical history, current coexisting medical conditions, self-reported history of imbalance, type of assistive device used for ambulation, and prescription medications used. All subjects completed the Mini Mental Test to determine mental status.[24] In addition, subjects completed the Balance Self-Perceptions Test, a tool used to examine subjects' perceptions regarding the degree to which balance and perceived risk for falls interfere with daily activities.[6] Subjects were asked to rate their degree of confidence (1=no confidence to 5=complete confidence) in performing 12 basic and instrumental activities of daily living without fear of loss of balance. The total score on this self-rating assessment can range from 0 to 60. Higher scores indicate the perception that balance and fear of falls do not limit performance of activities of daily living. The questionnaire is a modification of one developed by Tinetti et al[13] in their study of the relationship between fear of falling and measures of basic and instrumental activities of daily living.

Subjects then underwent a 45-minute performance-based evaluation of balance and mobility function. Balance was evaluated using the Berg Balance Scale, which rates performance from 0 (cannot perform) to 4 (normal performance) on 14 different tasks, including ability to sit, stand, reach, lean over, turn and look over each shoulder, turn in a complete circle, and step.[25] The total possible score on the Berg Balance Scale is 56, indicating excellent balance. The Berg Balance Scale has been shown to have excellent interrater reliability (.96) and relatively good concurrent validity with Tinetti's Performance-Oriented Mobility Index (.91) and Mathias' "Get Up and Go" Test (.76).[25–27]

Mobility was evaluated by asking subjects to walk 15.2 m (50 ft) at their preferred speed and then at their fastest pace. Subjects performed two trials in each condition. Subjects were timed, and mean speed was calculated for both self-paced gait speed and fast-paced gait speed. The Dynamic Gait Index[23] was used to evaluate the ability to adapt gait to changes in task demands. The Dynamic Gait Index rates performance from 0 (poor) to 3 (excellent) on eight different gait tasks, including gait on even surfaces, gait when changing speeds, gait and head turns in a vertical or horizontal direction, stepping over or around obstacles, and gait with pivot turns and steps.[23] Scores on the Dynamic Gait Index range from 0 to 24. The Dynamic Gait Index has been shown to have excellent interrater reliability (.96) and test-retest reliability (.98).[6]

Data Analysis

Histograms and descriptive statistics were calculated, using SPSS version 6 software,* to determine distributions, detect outliers, and consider the need for transformations.[28] There were no unusual distributions or outliers, and no transformations were needed.

We used *t* tests and cross tabulation with chi-square tests to determine which variables differed significantly ($P<.05$) between the fallers and the nonfallers.[29] Results from these analyses allowed the identification of individual variables from the original group of variables that

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

have a strong association with fall history. Spearman correlations among pairs of these variables were calculated to detect similar variables as well as those that had little overlap. Even though some of the variables were dichotomous, the Spearman correlation was judged to be appropriate for assessing the strength of association among these variables. The Spearman correlation coefficient can be used with continuous or ordinal variables. Dichotomous variables are simply a special case of ordinal variables. In addition, the use of Spearman correlations allowed the results to be presented in a consistent format.

The bivariate analysis was used to identify individual variables that were predictive of falling. Because it was probable that a combination of variables would improve the prediction of being a faller, a regression analysis was also carried out to identify any combinations of variables that would be superior to any single variable for predicting fall status. We carried out logistic regression analysis using a forward stepwise procedure, with fall history as the dependent variable (0=no falls, 1=two or more falls).[30] The group of variables with strong associations with fall history were the independent variables. The regression analysis yielded a model for the probability of being in the faller group. Sensitivity and specificity in predicting fall status were calculated for this model. Sensitivity and specificity were also calculated for logistic regression models, with each of several risk factors considered separately. For the purposes of our study, *sensitivity* was defined as the percentage of fallers who were correctly classified and *specificity* was defined as the percentage of nonfallers who were correctly classified.

Table 1.
Association of Risk Factors With Fall Classification

Risk Factor	Nonfallers (n=22)	Fallers (n=22)	*P* (test)
Age (y)			
$\bar{X}$	74.6	77.6	.2 (*t* test)
SD	5.4	7.8	
Range	65–86	65–94	
Gender (%)			
Female	68	77	.7 (χ^2)
Male	32	23	
No. of medications			
$\bar{X}$	2.2	1.7	.2 (*t* test)
SD	2.9	1.5	
Range	0–11	0–4	
Mini Mental Test (% impaired)	27	45	.2 (χ^2)
Assistive device (%)			
Any used	0	23	.05 (χ^2)
Cane only	0	14	
Walker only	0	9	
Berg Balance Scale			
$\bar{X}$	52.6	39.6	.0001 (*t* test)
SD	3.4	11.1	
Range	43–56	4–56	
Dynamic Gait Index			
$\bar{X}$	20.6	15.6	.001 (*t* test)
SD	2.9	5.7	
Range	5–20	2–20	
Balance Self-Perceptions Test			
$\bar{X}$	51.4	38.8	.01 (*t* test)
SD	3.4	15.1	
Range	46–60	4–56	
Self-paced gait speed (mph)			
$\bar{X}$	2.9	2.6	.3 (*t* test)
SD	0.9	0.9	
Range	1.6–5.0	1.1–4.2	
Fast-paced gait speed (mph)			
$\bar{X}$	4.3	3.7	.1 (*t* test)
SD	1.2	1.4	
Range	2.5–6.8	1.4–5.8	
History of imbalance (%)	41	95	.0002 (χ^2)

Results

Association of Risk Factors With Fall Classification

Fallers and nonfallers differed on 5 of 11 risk factors (Tab. 1). Analysis indicated that the two groups showed notable differences on the Berg Balance Scale, use of assistive devices, the Dynamic Gait Index, the Balance Self-Perceptions Test, and history of imbalance. Fallers tended to be more variable in their characteristics, as indicated by larger standard deviations.

Factors that showed nonsignificant differences between the two groups included age, gender, number of medications, self-paced gait speed, and fast-paced gait speed.

Correlation Among Risk Factors

The risk factors that were significantly associated with fall status were also correlated with one another. As shown in Table 2, significant Spearman correlations were found among almost all of the five clinical variables that predicted fall status. The highest correlations (r=.76) were found between the Dynamic Gait Index and the Balance Self-Perceptions Test and between the Balance Self-Perceptions Test and the Berg Balance Scale. The weakest and only nonsignificant correlation was found between history of imbalance and the use of an assistive device for ambulation.

Multivariate Model for Falls Classification

To construct a predictive model of fall risk, a forward stepwise logistic regression analysis was used. This procedure produces one model that is likely to be among the best predictive models for fallers, though other

Table 2.
Spearman Correlation Coefficients Among Risk Factors Significantly Predicting Fall Status

	Berg Balance Scale	Assistive Device	History of Imbalance	Balance Self-Perceptions Test
Assistive device	−.53[a]			
History of imbalance	−.50[b]	.24		
Balance Self-Perceptions Test	.76[a]	−.52[a]	−.60[b]	
Dynamic Gait Index	.67[a]	−.44[b]	−.46[b]	.76[a]

[a] $P \leq .001$.
[b] $P \leq .01$.

Table 3.
Logistic Regression Model for Falls

Risk Factor	Model Coefficient (SE)	P
Berg Balance Scale	−0.25 (0.10)	.01
History of imbalance	2.32 (1.17)	.05
Constant	10.46 (5.33)	.05

Table 4.
Sensitivity and Specificity of Fall Prediction From Individual Risk Factors[a]

Risk Factor	Cutoff Score	Sensitivity (%)	Specificity (%)
Berg Balance Scale	≤49	77	86
Dynamic Gait Index	≤19	59	64
Balance Self-Perceptions Test	≤50	73	82
History of imbalance	Yes	95	59
Assistive device	Yes	23	100
Berg Balance Scale and history of imbalance	++[b]	91	82

[a] Cutoff for all variables is selected to yield a predicted probability of falls of ≥0.5.
[b] ++ =history of imbalance was "no" and Berg Balance Scale score was ≤42 or history of imbalance was "yes" and Berg Balance Scale score was ≤51.

models are possible. The variables considered for this model were determined from the analysis of individual risk factors for falls and were the variables shown in Table 1 with probability values of $P<.05$. The variables that were considered were the Berg Balance Scale, the Dynamic Gait Index, the Balance Self-Perceptions Test, history of imbalance, and use of an assistive device.

The final model, shown in Table 3, included both the Berg Balance Scale and history of imbalance (coded as 0 for no history of imbalance and as 1 for a positive history of imbalance within the previous 6 months). The model is related to the probability of falling by the following equation:

$$\text{Probability} = 100\% \times \exp(10.46 - 0.25 \times \text{Berg Balance Scale score} + 2.32 \times \text{history of imbalance score})/[1 + \exp(10.46 - 0.25 \times \text{Berg Balance Scale score} + 2.32 \times \text{history of imbalance score})]$$

This model, for example, would predict that an individual with no history of imbalance (coded as 0) and a score of 54 on the Berg Balance Scale would have a predicted probability of falling of 5%. In contrast, an individual with a history of imbalance (coded as 1) and a Berg Balance Scale score of 42 would have a predicted probability of falling of 91%.

To further evaluate the model, we examined the sensitivity and specificity using the predicted probability of falls compared with the observed fall status of our sample. The cutoff value that jointly maximized both sensitivity and specificity was a predicted probability of 0.5 or larger used to designate a faller. With this cutoff value, sensitivity was 91% (20/22 fallers were correctly classified) and specificity was 82% (18/22 nonfallers were correctly classified).

Choosing a Clinical Test to Identify and Monitor Fall Risk in a Geriatric Population

Several of the risk factors had good sensitivity and specificity for predicting falls. Table 4 illustrates the sensitivity and specificity of fall risk associated with individual clinical measures as well as for the final model developed from stepwise logistic regression. Shown are the four clinical variables that were found to be predictors of fall risk. The cutoff score that corresponds to the probability value of 0.5 is also shown. We used the models for each risk factor to classify subjects as fallers or nonfallers, again choosing a predicted probability of 0.5 or larger to designate fallers. Based on this designation, we calculated sensitivity and specificity for each risk factor and its associated logistic regression model. For example, a score of 49 or less on the Berg Balance Scale corresponded to a predicted probability of 0.5 or larger, and it correctly classified 77% of people with a positive history of falls (sensitivity) and 86% of people who did not have any history of falls (specificity). A score of 19 or less on the Dynamic Gait Index correctly classified 59%

of those with a history of falls, while correctly classifying 64% of those without a positive fall history. As shown in Table 4, the optimal balance between sensitivity and specificity occurs when the Berg Balance Scale score is combined with history of imbalance.

The Berg Balance Scale appears to be the best single predictor of fall status (Tabs. 1 and 4). The predicted probability for falls as a function of the Berg Balance Scale score is plotted in the Figure. The results show that declining Berg Balance Scale scores were associated with increasing fall risk. This relationship, however, was nonlinear. In the range of 56 to 54, each 1-point drop in the Berg Balance Scale scores was associated with a 3% to 4% increase in fall risk. In the range of 54 to 46, a 1-point change in the Berg Balance Scale scores led to a 6% to 8% increase in fall risk. Below the score of 36, fall risk was close to 100%, and further declines in the Berg Balance Scale scores added little to the already extremely high fall risk. Thus, a 1-point change in the Berg Balance Scale score can lead to a very different predicted probability for a fall, depending on where the baseline score is in the scale.

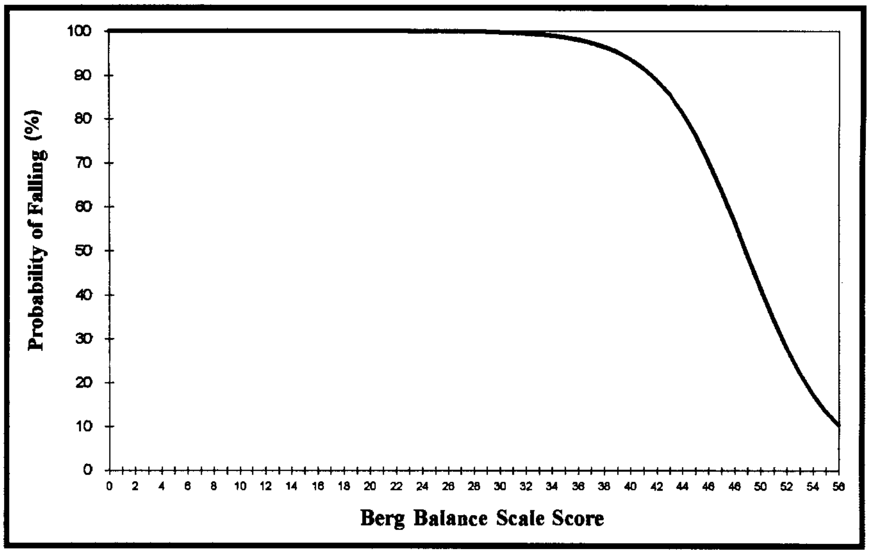

Figure.
Predicted probability for falls as a function of the Berg Balance Scale score.

Discussion

The purpose of this research was to develop a model for quantifying fall risk among community-dwelling older adults. The need to accurately and reliably quantify fall risk is based on the assumption that such a measure is essential to the appropriate referral of individuals at high risk into a fall prevention program. We believe that a valid and reliable measure of fall risk could also be used as an outcome measure for interventions designed to reduce an individual's risk for falls. In this case, the effect of the intervention could be assessed by the decrease in the estimated probability of falling from before to after the intervention.[6]

Eleven factors were originally considered as possible predictors of fall risk, based on a review of the literature. These factors included a range of demographic, medical, self-report, and performance measures related to balance function. An analysis of individual factors identified 5 variables that were significantly related to fall risk: the Berg Balance Scale score, the Dynamic Gait Index score, the Balance Self-Perceptions Test score, history of imbalance, and type of assistive device used for ambulation. Our results did not show that age, gender, or number of medications used predicted fall risk. Thus, our results are not completely consistent with the findings of other researchers who have reported that specific chronic diseases, health-related behaviors, age, and gender are predictive of fall risk in community-dwelling older adults.[4,31,32]

We found strong correlations among the clinical performance-based measures. This finding is not surprising, considering that all of these measures are purported to measure some aspect of balance and mobility function. This finding is consistent with data from other researchers who have reported strong correlations among commonly used clinical tools used to evaluate balance and mobility function in older adults.[33–35] We also found a strong correlation between the performance-based measures and our self-report measure, which is consistent with previous research.[13,33,36] These strong correlations suggest that some assessment measures can be used interchangeably for the purpose of assessing fall risk.

Our analysis demonstrated that the model with the best sensitivity and specificity included two factors: a performance-based measure of balance (the Berg Balance Scale) and a self-report measure of imbalance history (scored as "yes" or "no"). This model had a sensitivity of 91% and a specificity of 82%. Thus, 20 of the 22 fallers were correctly classified, and 18 of the 22 nonfallers were correctly classified. The sensitivity and specificity of this model were superior to any of the clinical variables used in isolation. The single variable that had the next best values of sensitivity and specificity was the Berg Balance Scale. The values of sensitivity and specificity for all models presented here are likely to be higher than those encountered when the predictive models are applied to a new population. This is a general phenomenon that occurs when models are developed on one data set and then applied to new data.

Understanding the meaning of an individual score on a clinical test is greatly enhanced by the ability to relate that score to relevant and meaningful events in a patient's life. The logistic regression model used in our study provides a link between performance on the Berg Balance Scale and risk for falls. Based on this model, the predicted probability for falls increases as the Berg Balance Scale scores decrease in a nonlinear relationship. A score of 56 on the Berg Balance Scale is associated with a 10% predicted probability of falls. As the Berg Balance Scale scores decrease, the predicted probability of falls rapidly increases. A score of 40 or lower is associated with a fall risk of nearly 100%. The model used in our study allows the quantification of relative fall risk. Rather than presenting fall risk as a categorical variable (faller versus nonfaller), the model allows the determination of a gradient of risk from 0 (low risk) to 100 (high risk). This feature of the model increases its value as a measure of change following intervention, because it allows the detection of a relatively small but clinically relevant change in fall risk.

The results of our study suggest that patients who score high on the Berg Balance Scale have a relatively low fall risk and should probably not be referred for further intervention. In contrast, patients who score 40 or less have a high probability for falls and are therefore appropriate for referral into a program designed to improve balance and mobility function and to reduce fall risk. The decision to refer a patient for therapy, however, is complex, often reflecting more factors than just the probability for falls. Individuals who live in their own home without the help and assistance of others and who perceive that their balance and mobility skills are declining may be referred for therapy even though they have a Berg Balance Scale score that is associated with a relatively low probability for falls. The potential consequences of not treating these individuals are great, because a fall leading to a fracture can result in a loss of independence, an extended stay in a skilled nursing facility, and in some cases death.[37–39]

Limitations of the Study

We examined variables that predict probability for falls among a small number of community-dwelling adults aged 65 years and older. The application of this research to individuals living in a skilled nursing facility or to individuals below the age of 65 years would be speculative. In addition, this study was carried out on volunteers. Had subjects been drawn at random from the community, the results might have been different.

Clinical Implications

The growing realization of the personal and economic costs of falls has led to the development of programs designed to reduce the frequency of falls and fall-related injuries among older adults. Because declining balance and mobility function are major factors leading to falls, an important emphasis in physical therapy is the development of interventions that are effective in improving balance and mobility function as a method for decreasing fall risk. As demand for these programs increases, there will be an accompanying need for assessments that effectively identify those individuals who are at risk for falls and that can measure outcomes associated with these programs. This preliminary study has shown a promising method for quantifying fall risk. Results from this initial study need to be confirmed with a larger community-based population.

Conclusions

Falls are a major health problem among elderly people. This research has developed a simple predictive model based on two risk factors that can be used by physical therapists to quantify fall risk in community-dwelling older adults. Assessing fall risk would allow the identification of individuals who would likely benefit from services designed to reduce the risk for further injurious falls. Reducing subsequent frequency of falls and fall-related injuries can result in a significant decrease in health-related costs, an essential consideration in the current managed health care environment.

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