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Original Article

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Fall predictors in the community dwelling elderly: A cross sectional and prospective cohort study

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Abstract

Objectives: To ascertain the risk factors for falls, stumbles and recurrent falls in a cohort of elderly people with mean age of 76.7±6.1 years. **Methods:** 137 community dwelling elderly living independently or in assisted living institutions participated in the study. Each subject was assessed by history, physical examination and physical performance tests at the beginning and end of study. Falls and stumbles were recorded in a falls dairy for 1 year. **Results:** Significant predictors of being a faller were a history of falls at baseline (Odds Ratio (OR) = 3.85, 95% Confidence Interval (CI) = 1.56 - 9.50), depression (OR = 1.19, 95% CI = 1.02 - 1.38) and timed rise (Incident Rate Ratio (IRR) = 1.24, 95 % CI = 1.03 - 1.50). For predicting recurrent fallers Receiver Operator Characteristic (ROC) curves were as follows: 0.71 (95%CI 0.61-0.81) for timed up and go, 0.67 (95%CI 0.56-0.78) for timed rise and 0.70 (95%CI 0.60-0.80) for timed walk fast pace. **Conclusions:** Timed rise was the single most important test that was able to predict both a first time faller and recurrent faller. Timed up and go was the most significant test to predict recurrent fallers.

Keywords: Community Dwelling Elderly, Fallers, Physical Performance Test

Introduction

Falls are the leading cause of both fatal and other injuries for adults aged ≥65 years[1]. In 2005, around 15,800 adults aged ≥65 years in the USA died from injuries related to unintentional falls and non fatal injuries led to the admission of about 1.8 million people ≥65 years in emergency departments[2] with an expenditure of around $19 billion in the year 2000.

Falls can lead to a variety of serious consequences especially fractures (6%) and traumatic head trauma (6%)[3].The most common fracture after a fall is hip fracture with long term consequences for the elderly[4]. Falls can also have a detrimental impact on functional ability of elderly people[4].

A number of studies have been conducted in the past to determine the risk factors associated with falls in the elderly[4-14,16]. Despite the fact that these studies reported an association between falls and physical performance, most of the multifactorial intervention strategies based on these for the prevention of falls in elderly have been only partially successful because they reduce the recurrent falls in some individuals but not the actual number of "fallers"[15]. There have been no studies (which the authors are aware of), analyzing the risk factors for cumulative falls, cumulative stumbles, fallers and recurrent fallers in one single study population. Although the interventions for fall prevention have demonstrated cost effectiveness[16], there is little data on the time duration and intensity with which these may be carried out.

We planned to perform a prospective study for one year to ascertain the incidence of falls and recurrent falls, recognize the risk factors and determine the efficacy of an objective set of physical performance measures in predicting the fall and recurrent fall risk in a cohort of elderly people representative of the general population of elderly living in the community.

Methods

This was a cross sectional and prospective cohort study conducted at Creighton University Medical Center. The subjects were community dwelling elderly people living in the city area of Omaha and surrounding districts who were contacted through an advertisement that stated that we were conducting

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a falls study. The advertisements were placed in local newspapers and in fliers in assisted living communities, between May 2002 and April 2003. The initial screening consisted of a medical and lifestyle history and review of systems. Of the 173 people who came for initial screening, 137 were recruited based on the inclusion criteria: age between 65-85 years and living independently in the community or in the assisted and independent living institutions. The exclusion criteria were age <65 or >85 years and/or a documented history of central nervous system disorders including stroke/paralysis, Parkinson's disease, Alzheimer's disease (Mini Mental Status Examination (MMSE) <21). All the participants signed an Institutional Review Board (IRB) approved consent form for the study before any screening procedures were performed.

The recruited subjects (137) then underwent baseline assessment of physical performance variables and a heel ultrasound. They were given fall diaries to complete whenever they had a fall or stumble while on study i.e. for 1 year. This was followed by monthly telephone calls. At the end of the study, all the measurements were repeated. A serum 25 hydroxyvitamin d (25-OHD) level was also measured at the end of the study. The study protocol was approved by the Institutional Review Board of Creighton University.

Data Collection

The health assessment was done by self administered questionnaires and interviews conducted by trained clinical staff.

The medical history consisted of: (a) patient demographics including dominant hand and leg, use of any assistive devices, type of footwear, (b) past medical history including last screening test, history of any major past illness like depression, cognitive impairment, visual impairment, auditory impairment, physical disability, Parkinson's disease, stroke, heart disease, hypertension, lung disease, osteoporosis, scoliosis, diabetes, urinary incontinence, joint disease and cancer, (c) medication history - use of any hypnotics, sedatives, antihypertensives, antidepressants, cardiac medications, diuretics, hypoglycemic agents, opiates, steroids, Non steroidal anti-inflammatory drugs and multivitamins; subjects taking sedatives, hypnotics or antidepressants were classified as taking neuroactive medications, (d) past surgical history (e) nutritional history (f) reproductive history (g) history of smoking, alcohol and caffeine intake and (h) environmental hazards - by means of a home safety checklist.

A Lawton Instrumental Activities of Daily Living Questionnaire (IADL)[18] was used in the study and scored according to FICSIT (Frailty and Injuries: Cooperative Studies of Intervention Techniques) form[17]. Higher scores indicated better level of functioning. It is reliable (reproducibility coefficient >0.90)[17] and valid[19]. Geriatric Depression Scale (GDS) is a 30 question scale designed specifically for rating depression in the elderly[20]. Scores were the sum of all the depressive symptoms and indicated the level of depression - higher score indicates more depression. It is reliable (test retest and inter - rater reproducibility coefficients >0.80) and has a high sensitivity and specificity in the diagnosis of depression[17]. Folstein MMSE was used to determine higher mental functions. Scores ranged from 0 to 30. Higher score pointed towards normal and lower scores toward dementia. Physical Activity Scale for the elderly (PASE) was used to access and quantify the physical activity level in the study subjects as mentioned in our previous paper[21].

Physical Examination included measurements of weight, height, body mass index (BMI), pulse and blood pressure - measured in both sitting and standing positions with the subject being seated for at least 5 minutes before beginning.

Physical Performance Tests

These tests involved evaluation of: (a) muscle strength (grip strength for upper extremity and knee extensor strength for lower extremity), (b) agility and coordination (timed rise), (c) gait and balance (quiet stance, tandem gait, timed up and go, timed walk - normal and fast) and (d) postural stability tests. Grip strength and timed walk (at both normal and brisk pace) were performed as outlined in our previous paper[21]. Grip Strength was measured by a handheld JAMAR dynamometer (Jackson, MI). Knee Extensor Strength was measured by a JTECH power II commander dynamometer. The subjects sat on a chair and from 90 degree flexion of knee, they applied extension force with their shin against the dynamometer held in examiner's hand. This test measured the isometric knee extensor strength and was done in dominant leg. An average of 3 values was used in the final analysis. This test is reliable (test – retest/intraclass reliability coefficient >0.97)[23]. Timed Rise involved the time taken by a subject to rise from a chair as quickly as possible. This test was performed as described[24]. It is reliable (r = 0.80) and valid[22].

Timed Up and Go was performed as described previously[25], with some modifications. It was assessed as the time taken by a subject to get up from a chair (with arms crossed across the chest), walk 10 feet, turn around, walk back and sit down as quickly as possible. They were not allowed to use their arms and this is somewhat more difficult than the original test. The original test is reliable and correlates well with scores on the Berg Balance Scale (r = -0.81) and gait speed (r = -0.61)[25]. For quiet stance measurement, the participants were asked to stand quiet for fifty seconds twice at one minute intervals both with eyes open and closed. For tandem gait subjects were asked to stand in a tandem position and walk along a straight line of 15 feet length with heel to toe movement. Postural stability was measured by Balance System SD (Biodex Medical Systems, NY). The participants stood on a movable platform, default settings were made and subject's ability to control the platform variance from a perfectly balanced position was measured. The test was repeated three times with eyes open and overall body sway (OBS), anterior-posterior body sway (APBS) and medial-lateral body sway (MLBS) were measured. A subject with poor balance had a higher score and vice-versa. This test is reliable and valid for the identification of disequilibrium in elderly[22].

Heal Ultrasound was done using an Achilles Ultrasound densitometer using the procedure described by manufacturer.

	Female Non Fallers	Female Fallers	Male Non Fallers	Male Fallers
N	29	60	13	35
Age, years	74.1 ± 6.0	77.1 ± 6.2*	79.2 ± 5.0	77.3 ± 5.8
BMI	26.9 ± 3.8	28.9 ± 5.0	26.7 ± 2.6	28.6 ± 4.5
Systolic BP	127.6 ± 19.7	138.8 ± 19.7*	135.5 ± 20.1	133.3 ± 18.1
Diastolic BP	66.0 ± 11.0	70.8 ± 11.0	64.2 ± 9.4	68.7 ± 10.5
Heal Ultrasound Stiffness	78.0 ± 17.9	73.9 ± 18.7	92.9 ± 16.0	86.2 ± 22.3
Geriatric Depression Score	3.2 ± 2.4	6.1 ± 4.4*	3.1 ± 2.0	7.6 ± 5.0†
Mini-mental status	29.0 ± 1.1	28.7 ± 1.5	28.0 ± 1.6	28.1 ± 2.0
Age at Menopause, years	49.6 ± 4.6	48.0 ± 6.7		
Assistive Devices, N (%)	1 (3%)	20 (33%)*	1 (8%)	10 (29%)
Smokers (past yr)	4 (14%)	3 (5%)	0 (0%)	1 (3%)
Alcohol drinkers (past yr)	17 (58%)	22 (37%)	7 (54%)	24 (69%)
Caffeine users (past yr)	16 (55%)	31 (52%)	7 (54%)	25 (71%)
Hysterectomy	12 (41%)	36 (60%)		
Estrogen use	11 (38%)	38 (63%)*		
Neuroactive medications	2 (7%)	24 (40%)*	2 (15%)	9 (26%)
Medication Use				
0-1	10 (34%)	9 (15%)	5 (39%)	11 (31%)
2-3	14 (48%)	28 (47%)*	6 (46%)	12 (34%)
>=4	5 (17%)	23 (38%)*	2 (15%)	12 (34%)
Instrumental Activities of Daily Living				
6-8	3 (10%)	9 (15%)	3 (23%)	12 (34%)
9	26 (90%)	51 (85%)	10 (77%)	23 (66%)
Number of Comorbidities				
0-3	25 (86%)	22 (37%)	7 (54%)	13 (37%)
4-5	4 (14%)	21 (35%)*	5 (38%)	13 (37%)
>=6	0 (0%)	17 (28%)*	1 (8%)	9 (26%)

Notes: n = number of people analyzed.
Values are shown as unadjusted means ± standard deviation (SD) and as number of people in that group, N (%).
Categorical variables were analyzed by chi-square or Fisher's test and continuous variables by t-test.
*p<0.05 compared to female non fallers.
†p<0.05 compared to male non fallers.

Table 1. Baseline demographics by history of falls (n=137), separately for males and females.

Outcome

There were four outcomes of this study: (a) cumulative number of falls, (b) cumulative number of stumbles (c) fallers and (d) recurrent fallers. A fall was defined as" unintentionally coming to rest on the ground, floor or other lower level". Coming to rest against furniture, wall, or other structure did not count as a fall[17]. A stumble was defined as an event where the subject almost fell but was able to catch himself/herself or to stop the fall[17]. Cumulative number of falls meant the total fall events that the subjects experienced during study year. A "faller" was defined as a person who had at least 1 fall during the study. Recurrent fallers were defined as those who had a history of fall at baseline (in the last 12 months) and again fell during the study year or had ≥ 2 falls during the study year. The fall data was assessed using a self-reported fall questionnaire at baseline and from fall diaries at the end of the study.

Biochemical Analysis

At the end of 12 month study period, serum 25OHD was measured in all subjects. The blood samples were allowed to clot for 1 hour on ice and then centrifuged for 20 minutes at 3400 rpm in the J6B centrifuge at 4 degree Celsius. Serum was stored in 0.5 ml aliquots at -70 degree Celsius until analysis. Serum 25OHD levels were measured by a radioimmunoassay technique (Diasorin, Stillwater, MN) after acetonitrile extraction. The limit for serum 25OHD detection range in our laboratory was 5 nanograms per milliliter and inter-assay variation and intra-assay variations were 9.8% and 9.2 % respectively.

Variable	Female Non fallers	Female fallers	Male Non fallers	Male fallers
PASE score	120.36 ± 7.65	80.31 ± 5.27*	117.17 ± 12.17	74.81 ± 7.12†
Grip Strength	23.57 ± 0.87	21.40 ± 0.60*	31.43 ± 2.04	29.79 ± 1.21
Knee Extensor Strength	15.06 ± 0.96	13.29 ± 0.54	22.77 ± 1.71	17.68 ± 1.02†
Timed Rise 5 times	14.98 ± 1.17	17.42 ± 0.82	16.36 ± 1.76	19.43 ± 1.05
Timed Rise 3 times	7.18 ± 0.67	9.15 ± 0.50*	8.86 ± 1.09	10.63 ± 0.68
Timed Up Go	10.96 ± 0.98	12.01 ± 0.71	9.64 ± 0.93	12.32 ± 0.57†
Timed Walk Normal Pace	5.05 ± 0.29	5.75 ± 0.20	5.87 ± 1.78	7.01 ± 1.07
Timed Walk Fast Pace	3.98 ± 0.21	4.29 ± 0.14	3.47 ± 0.26	4.30 ± 0.16†
Overall Body Sway	3.73 ± 0.28	4.17 ± 0.19	4.74 ± 0.46	5.73 ± 0.28
Anterior Posterior Body Sway	2.70 ± 0.21	3.25 ± 0.14*	3.51 ± 0.39	4.41 ± 0.24
Medial Lateral Body Sway	2.74 ± 0.21	2.71 ± 0.14	3.36 ± 0.33	3.73 ± 0.20
Quiet Stance eyes open, N (%)				
Swayed	8 (28%)	11 (18%)	2 (15%)	7 (20%)
Able to Stand	21 (72%)	49 (82%)	11 (85%)	28 (80%)
Quiet Stance eyes closed, N (%)				
Swayed	13 (45%)	23 (38%)	7 (54%)	15 (43%)
Able to Stand	16 (55%)	37 (62%)	6 (46%)	20 (57%)
Tandem Gait, N (%)				
Swayed	21 (72%)	57 (95%)*	10 (77%)	34 (97%)
Able to complete without difficulty	8 (28%)	3 (5%)	3 (23%)	1 (3%)

Notes: N = number of people in the respective groups; PASE = Physical Activity Scale for the Elderly.
Data presented as adjusted means ± standard errors unless otherwise noted.
Using Analysis of Covariance (ANCOVA), the models were adjusted for significant confounding baseline variables out of the following: number of comorbidities, number of medications, Assistive Devices, neuroactive medications, past 12 month smoking status, past 12 month alcohol use, past 12 month caffeine use, Instrumental Activities of Daily Living score, age, Geriatric Depression Scale, Mini Mental Status Examination (MMSE), Body Mass Index (BMI), Systolic BP, Diastolic BP, Heal Ultrasound Stiffness, Hysterectomy, and Estrogen use.
*$p<0.05$ compared to female non fallers.
†$p<0.05$ compared to male non fallers.

Table 2. Baseline physical performance variables by history of falls at baseline - Multivariate cross sectional analysis.

Statistical Analysis

Data were analyzed with the SAS statistical package V9.2 (SAS Institute Inc., Cary, NC). Baseline patient characteristics were compared by history of falls at the beginning of the study, separately for men and women, using t-tests for continuous variables and chi-square tests for categorical variables. Baseline physical performance variables were compared by history of falls using analysis of covariance (ANCOVA), separately for men and women while adjusting for confounding variables at baseline. Backward selection was used to select significant confounders to include in the model. An alpha level of 0.05 was used for model selection. Data are summarized with adjusted means and standard errors. For dichotomous outcomes, the above procedure was the same only using logistic regression. This was followed by a prospective analysis of cumulative number of falls/stumbles and fallers at 12 months. Univariate and multivariate logistic regression was used to look at fallers, with baseline demographic variables and history of falls included in a forward variable selection routine (with an entry criteria of p=0.05) in the multivariate modeling. Poisson regression models were also used to examine the ability of the physical performance variables at baseline to predict the cumulative falls/stumbles at 12 months after adjusting for significant covariates found from model selection. Receiver Operator Characteristic (ROC) Curves were then made for predicting recurrent fallers by baseline physical performance variables and Area Under Curve (AUC) was calculated for each curve. For all analyses p-values less than 0.05 were considered statistically significant.

Results

Baseline Characteristics

Out of a total of about 137 people, 69.3 % were fallers at baseline. The mean age was 76.7±6.1 years and there was no significant difference in the two groups. However, fallers had higher rates of use of assistive devices, greater number of comorbidities, higher medication use in general and specifically a greater use

Variable	Risk of Cumulative Falls		Risk of Cumulative Stumbles		Risk of being a Faller	
	IRR*	95 % Confidence interval	IRR	95 % Confidence interval	OR†	95 % Confidence interval
PASE	1.00	0.995 - 1.005	1.00	0.99 - 1.01	1.00	0.99 - 1.01
Grip Strength	1.01	0.98 - 1.04	1.00	0.96 - 1.04	0.98	0.93 - 1.04
Knee Extensor Strength	1.00	0.97 - 1.03	1.02	0.98 - 1.06	0.97	0.91 - 1.05
Timed Rise 5 times	1.02	1.00 - 1.04{	0.98	0.95 - 1.02	1.10	1.00 - 1.20{
Timed Rise 3 times	1.04	1.00 - 1.08{	1.00	0.94 - 1.06	1.24	1.03 - 1.50{
Timed up and go	1.02	0.98 - 1.05	0.94	0.88 - 1.00	1.07	0.96 - 1.20
Timed walk normal pace	1.01	0.92 - 1.11	0.83	0.72 - 0.96{	1.30	0.93 - 1.82
Timed walk fast pace	1.03	0.89 - 1.18	0.79	0.64 - 0.98{	1.20	0.82 - 1.77
Overall Body Sway	1.18	1.05 - 1.33{	0.90	0.76 - 1.06	1.17	0.87 - 1.58
Anterior Posterior Body Sway	1.16	1.00 - 1.35{	0.87	0.71 - 1.08	1.08	0.75 - 1.56
Medial Lateral Body Sway	1.26	1.08 - 1.47{	0.89	0.72 - 1.11	1.40	0.92 - 2.13
Quiet Stance Eyes Open‡	1.07	0.65 - 1.75	0.78	0.42 - 1.45	2.23	0.72 - 6.93
Quiet Stance Eyes Closed‡	0.88	0.58 - 1.34	0.77	0.48 - 1.25	1.76	0.72 - 4.31
Tandem Gait	1.39§ 1.77‖	0.55 - 3.55 0.72 - 4.36	1.61§ 2.34‖	0.54 - 4.79 0.83 - 6.58	2.02§ 3.29‖	0.46 - 8.94 0.81 - 13.43

Notes: n = number of people analyzed.
* IRR = Incident Rate Ratio after adjusting for the significant covariates including gender, number of comorbidities, number of medications and neuroactive medications.
† OR = Odds Ratio after adjusting for history of falls at baseline and geriatric depression score.
‡ IRR/OR of cumulative falls/stumbles in those who staggered during this test vs. those who didn't.
§ IRR/OR of cumulative falls/stumbles in those who were not able to perform the test compared to those who performed the test without any difficulty.
‖ IRR/OR of cumulative falls in those who staggered during the test compared to those who performed the test without any difficulty.
{ P value<0.05.

Table 3. Multivariate overdispersed Poisson regression model to predict the number of cumulative falls/stumbles at 12 months and adjusted logistic regression models to predict 12 month fall status (faller vs. non faller) using baseline physical performance variables (n = 112).

of neuroactive medications, higher BMI, higher diastolic blood pressure, greater depression and high past estrogen use among women. There were some sex specific differences also.

Females fallers were older, used assistive devices more often, had a higher number of co-morbidities, greater rate of medication use especially neuroactive medications, higher systolic blood pressure, high depression score and used estrogen more as compared to the female non fallers ($p<0.05$). Male fallers had a greater depression score ($p<0.001$) than male non fallers (Table 1).

Physical Performance Variables

The results of cross sectional analysis are shown in Table 2.

Prospective Analysis

Of the 137 participants enrolled, a total of 112 (82%; 78 females (88%) and 34 males (76%)) people completed the study. There were significant differences between them and the drop outs. Of the 25 (18 %) drop outs, 2 died, 9 had worsening health problems (including stroke and cancer), 9 were not interested, 3 moved out of town and 2 had family problems. The drop outs were older, more frequently males, had lower MMSE and PASE score, slower on most physical performance tests and were more frequently fallers at baseline.

Of the final 112 people, 70 fell in the follow up year with 46 (66%) females and 24 (34%) males. The incidence rate of falls was 59 % in females and 71 % in males ($p=0.24$). Serum 25 OHD levels were not significantly different in fallers vs non-fallers at the end of study (Mean ± SD in fallers = 23.48±7.66 ng/ml vs 26.12±7.58 ng/ml in non-fallers, $p = 0.084$).

Of the 70 fallers, 54 (77%) were in the initial fall group and 16 (23%) were in the non fall group at baseline. The association of being a faller at baseline and being a faller in the follow up period was highly significant ($p<0.0001$) (data not shown).

Consequences of Falls

Out of the 70 people who fell, 39 (55.7 %) reported injurious falls. The most common injury after a fall was bruising reported by 18 people (46%), followed by abrasions in 12 (30.7%), lacerations in 6 (15.3%) and fractures in 3 (7.7%) people. This led to 22 clinic and/or emergency room visits in 14 people.

The number of co-morbidities and geriatric depression score

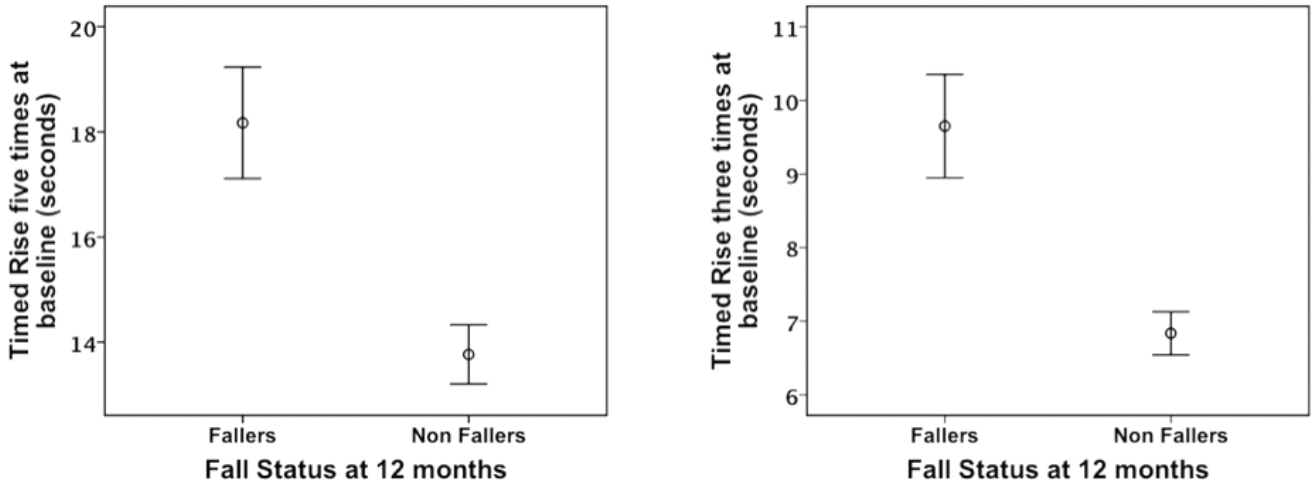

Figure 1. Time Rise (both three and five times) as predictor of being a faller at 12 months. Mean ± Standard error for timed rise five times was 18.17±1.06 in fallers vs 13.77±0.56 in non-fallers ($p<0.01$); timed rise three times was 9.65±0.7 in fallers vs 6.83±0.3 in non-fallers ($p<0.01$); p value calculated by independent t test.

were significant predictors of being a faller at 12 months (OR= 3.71 for >3 comorbidities, 95 % CI: 1.14 - 12.0; OR for geriatric depression score = 1.23, 95 % CI: 1.05 - 1.44)

However, when history of falls in the past year was also considered in the model, the number of co-morbidities was no longer significant (p=0.09). A history of falls at the baseline (OR= 3.85, 95 % CI 1.56 - 9.50) and the geriatric depression score (OR = 1.19, 95 % CI: 1.02 - 1.38) were significant predictors of being a faller at 12 months.

Timed rise was the only significant predictor of being a faller at 12 months after adjusting for history of falls and geriatric depression score (Table 3, Figure 1).

Timed rise three times, OBS, APBS and MLBS were significant predictors of cumulative number of falls at 12 months (Table 3).

Timed up and go and timed walk (at both normal and brisk pace) were significant predictors of cumulative number of stumbles at 12 months (Table 3).

Out of the 112 people who completed the study, 60 (54%) were recurrent fallers. The AUC for ROC curves for predicting recurrent fallers was: 0.35 (95% Confidence interval, CI 0.25 – 0.45) for knee extensor strength, 0.66 (95% CI 0.56-0.76) for timed rise five times, 0.67 (95% CI 0.56-0.78) for timed rise three times, 0.71 (95% CI 0.61-0.81) for timed up and go, 0.66 (95% CI 0.56-0.76) for timed walk normal pace, 0.70 (95% CI 0.60-0.80) for timed walk fast pace, 0.64 (95% CI 0.54-0.75) for OBS and 0.66 (95% CI 0.56-0.76) for MLBS (all $p<0.01$ except OBS where $p = 0.011$) (some important ones are shown in Figure 2). The AUC for other physical performance variables including grip strength, APBS, quiet stance and tandem gait was not significant (data not shown).

This was followed by an analysis of serum 25 OHD quartiles with the cumulative number of falls/stumbles. No significant associations were found (data not shown).

Discussion

Falls have become a major public health problem of the aging population. Previous studies have reported many risk factors for falls including a history of fall, lower extremity weakness, balance and gait abnormalities, decreased muscle strength, old age, cognitive impairment, medications, orthostatic hypotension, anemia, female gender, arthritis and psychological factors[5-14,16]. However, these differ among different studies. This is the first study of its kind to have analyzed the risk factors associated with cumulative falls, cumulative stumbles, fallers and recurrent fallers in one single study group. We performed a battery of physical performance tests to identify the elderly at high risk of falling. The incidence of falls in this community dwelling elderly cohort was around 62.5 % with non significant differences between males and females. This is somewhat higher than found in previous studies[26].

It was also found that there were different risk factors for different outcomes, suggesting that fall prevention strategies may have to be individualized to each specific outcome and in the process delineating the specific population which may benefit from such interventions.

There were gender specific differences at the baseline between fallers and non fallers. PASE was significantly lower in both the male and female fallers but female fallers were more unsteady on tandem gait, had weak hand grip strength, were slower on timed rise and had more APBS compared to non fallers while male fallers had weak knee extensor strength compared to non fallers, similar to previous reports[3,6,12], however these findings have to be carefully interpreted because of reduced statistical power due to small sample size.

In the prospective follow up, a history of falls at baseline, higher geriatric depression score and timed rise were the most significant predictors of being a faller at 12 months and timed

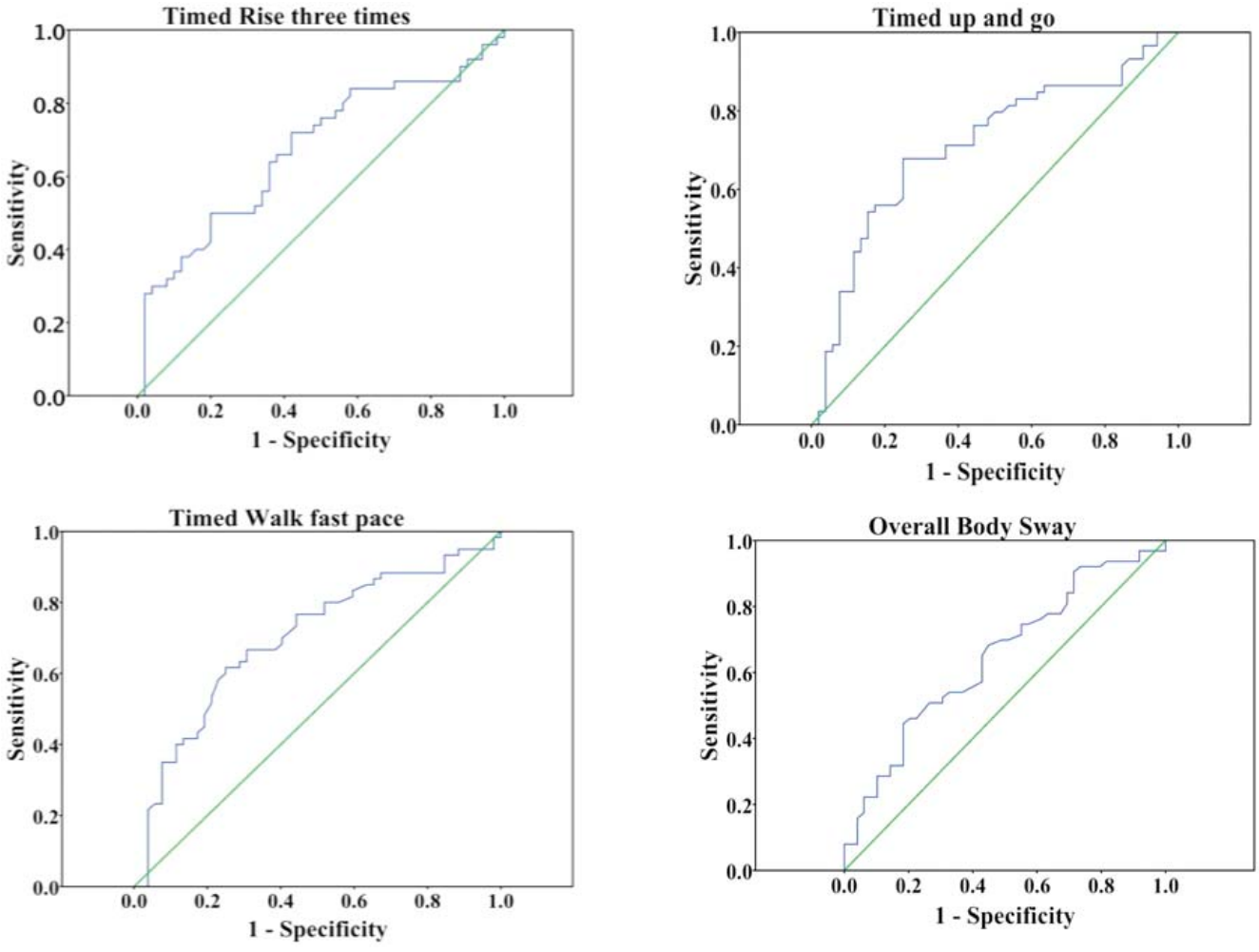

Figure 2. Receiver Operator Characteristic (ROC) curves of significant physical performance variables for predicting recurrent fallers are shown. The Area Under Curve (AUC) for these is: Timed rise three times = 0.67 (95% CI 0.56-0.78), Timed up and go = 0.71 (95% CI 0.61-0.81), timed walk fast pace = 0.70 (95% CI 0.60-0.80) and overall body sway = 0.64 (95% CI 0.54-0.75)
CI = Confidence Interval.
P values for all < 0.01 except for overall body sway where p = 0.011.

rise, OBS, APBS and MLBS were the most significant predictors of cumulative falls in a cohort of community dwelling elderly. These results are similar to those found in previous studies[6-8].

The Biodex system measures neuromuscular control by quantifying the ability to maintain dynamic bilateral and unilateral postural stability on a static or unstable surface. Although MLBS has been identified as a risk factor for falls[14] we also found a significant association with APBS, similar to the results of a recent study[27].

Depression was one of the predictors of being a faller and the underlying mechanism has been thought to be mediated through a loss of self confidence and increased anxiety in performing the activities of daily living. Recently, this association was given a more objective relationship[28]. This study showed an association between depression and gait unsteadiness: they found that patients with major depressive and bipolar disorders had greater swing time and stride time variability. When we performed a correlation analysis of GDS and body sway, we found significant correlation between the two (Pearson coefficient, r = 0.25 for GDS and OBS: p = 0.004). However, this correlation has to be carefully interpreted as use of neuroactive medications in depression may increase the body sway.

Timed rise is considered to be an important test to identify elderly fallers[7,9-10] and measures the lower extremity power. In our study, it was a significant predictor of fallers, recurrent fallers and cumulative falls at 12 months. However, timed up and go[25] which is one of the best known tests for screening elderly people was not able to differentiate between fallers and non fallers as shown in some recent studies[29] although it was a significant predictor of recurrent fallers (Figure 2). This points to a greater role of lower extremity power and sitting balance parameters for differentiating fallers from non fallers (timed rise)

and higher significance of gait and coordination parameters for identifying recurrent fallers. These findings suggest that in addition to lower extremity strength training, balance and gait training measures may also play a role in improving outcomes. This is in line with a recent systematic review of a large database which shows that a combination of both strength and balance training exercises like Tai Chi significantly reduces both the rate of falls and risk of falling (fallers)[15].

This study also showed that serum 25 OHD levels were not able to predict the risk of falling or stumbling at 12 months. Moreover, as timed up and go and timed walk normal and brisk pace increased the risk of stumbling actually decreased. This may imply that stumbles are associated with risk factors, other than those associated with falls. However, more studies are needed to identify the risk factors associated with stumbles and the importance of stumbling in predicting future fall risk in the elderly.

The ROC curves clearly show that a greater number of physical performance variables can predict recurrent fallers from those who had one fall. We found that knee extensor strength, timed rise five and three times, timed up and go, timed walk normal and fast pace, OBS and MLBS were significant predictors of recurrent fallers. Timed up and go was one of the most significant predictors of recurrent fallers. This suggests that it may be easier to differentiate between recurrent fallers and "non and one time" fallers than between once fallers and non fallers as shown in previous studies[30].

There were several strengths to this study. This is a first study of its kind where we identified risk factors for various outcomes like cumulative falls, cumulative stumbles, fallers and recurrent fallers and compared them across groups. The study subjects were free living, community dwelling elderly and those living in assisted, independent living institutions. Although this makes the sample relatively more representative of general population these observations might not be generally applicable since the sample was not randomly selected. Falls were ascertained by fall diaries and each study subject was followed by telephone calls every month. This is important as falls tend to be forgotten if they are non-injurious[31]. The physical performance tests used to assess the elderly in this study were all standardized and well validated. Also, all the data was analyzed separately for males and females during cross sectional analysis.

However, there were certain limitations. The study was conducted in a small sample of community that might have influenced the predictive value and statistical power. The selection of people based on their response to our advertisements highlighting a falls study may have introduced a selection bias in favor of recruiting fallers especially in the males in whom the fall rate is higher in our study than generally seen. The confounding variables like serum PTH, Creatinine and visual acuity were not evaluated which have been identified as risk factors for falls in some previous studies[32,33]. Although the environmental factors were asked for in the beginning of study, they were not properly analyzed.

In summary, this study shows a high risk of falls in an elderly ambulatory and free living group and emphasizes the fact that risk factors associated with cumulative falls, cumulative stumbles, fallers and recurrent fallers are different and it is easier to identify recurrent fallers than one time fallers. Timed rise was the single most important test which was able to predict all the outcomes of the study. Timed up and go was the most important test for predicting recurrent fallers. These tests are easy to perform using simple techniques and were more significant predictors of fallers than more sophisticated measures like body sway and knee extensor strength. These different risk factors for various outcomes also suggest that novel fall prevention strategies may be beneficial for specific subgroups of elderly like those based on number of falls but further research is needed in this field. Our study also underscores the importance of obtaining a good medical history, asking about a previous history of falls and screening depression as a way to recognize fall risk in the elderly. However, in future larger prospective studies with random recruitment strategies are required to confirm the findings of this study.

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