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Functional Mobility Discriminates Nonfallers From One-Time and Frequent Fallers

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Background. Given that 90% of hip fractures result from a fall, individuals who fall frequently are more likely to be at greater risk for fracture than one-time fallers. Our aim was to determine whether performance variables associated with injurious falls could be used to distinguish frequent fallers from both one-time fallers and nonfallers.

Methods. A total of 157 men and women (77.4 ± 5.4 years) were recruited and categorized into one of the following three groups based on falls status over the previous 12 months: nonfallers ($n = 48$), one-time fallers ($n = 56$), and frequent fallers (more than one fall) ($n = 53$). All subjects were evaluated on functional mobility and lower extremity strength and power.

Results. Using multivariate analysis of covariance with height as a covariate, nonfallers were significantly faster than both one-time and frequent fallers during the Get Up and Go (a test involving lower extremity strength and power, and mobility) and faster than one-time fallers on the Tandem Gait ($p < .01$). There were no significant differences between groups for other mobility variables or for laboratory measures of strength and power. Because one-time and frequent fallers were similar on all measures, they were grouped as “fallers” in discriminant analysis. The Get Up and Go discriminated between the fallers and nonfallers with a final Wilks’s Lambda of .900 ($p < .001$) and correctly classified 72.4% of fallers and nonfallers before crossvalidation and 71.2% of the cases after validation.

Conclusions. Given that the Get Up and Go discriminates between fallers and nonfallers and is associated with lower extremity strength and power, fall prevention strategies should focus on improving both functional mobility and lower extremity strength and power.

HIP fractures in the elderly account for a large portion of the disability and mortality experienced by older Americans each year (1). The costs of nursing and medical services related to hip fracture have been estimated at $10 billion annually and are expected to increase with the continued growth in the elderly population (2). Given that 90% of hip fractures result from a fall, individuals who fall frequently are more likely to be at greater risk for fracture than one-time fallers (3,4). Furthermore, falling to the side increases the risk of hip fracture sixfold, and it is speculated that frequent fallers are more apt to fall sideways, thereby increasing their risk of hip fracture (2,5).

Factors that contribute to increased risk of injurious falls in the elderly include decrements in lower extremity strength and power and certain characteristics of gait (6,7). Lee and Kerrigan (6) reported that fallers exhibited significantly lower peak torque during ankle dorsiflexion, plantar flexion, inversion, eversion, and hip adduction. These joint movements are thought to play a role in the control of postural stability. Ankle plantar flexion power is associated with step length reductions and reductions in gait velocity in older adults (8,9). Lord and colleagues (10) found that recurrent fallers had significantly slower and more variable cadence than both one-time fallers and nonfallers and that reduced quadriceps strength was associated with slow walking speed. In addition, fallers have significantly greater decreases in strength, reduced endurance of the quadriceps, and decreased time to fatigue of the quadriceps compared with nonfallers (11,12).

While investigators have reported that nonfallers perform better than fallers on both clinical mobility and laboratory measures of function, no one has examined nonfallers compared with one-time fallers and frequent fallers with respect to these measures. Our aim was to determine whether decrements in performance variables associated with injurious falls could be used to distinguish frequent fallers from both one-time fallers and nonfallers. We asked the following research questions: (i) Do frequent fallers differ from one-time fallers and nonfallers with respect to lower extremity strength and power, and functional mobility tests?, and (ii) Do measures of lower extremity strength and power or measures of functional mobility better discriminate among these three groups?

Methods

Subjects

A total of 157 subjects were recruited from the Mid-Willamette Valley in western Oregon. Of these, 131 were women (mean age 77.06 ± 5.42 years) and 26 were men (mean age 78.9 ± 5.51 years) (Table 1). All subjects were living independently in their own homes, retirement centers, or assisted living facilities. Prior to participation, individuals completed a number of questionnaires including health history forms and a detailed medication survey. Individuals who were able to complete all of the paperwork without any apparent disorientation, confusion, or memory impairment were considered to be cognitively competent and allowed to participate. Individuals were characterized as nonfallers, one-time fallers, or frequent fallers based on the number of falls they had experienced over the previous 12 months. Frequency of falls and characteristics of falls were determined from a combination of controlled falls surveillance and self-reported falls information. A fall was defined as "an event that results in a person coming to rest unintentionally on the ground or other lower level" (12). Coming to rest on the ground as a clear result of an externally applied force (such as being struck by an automobile) or a specific neurological disorder (such as Parkinson's disease) was not recorded as a fall. Each potential participant was interviewed using a standardized questionnaire regarding the nature and circumstances of each fall to ensure that all falls characterizing one-time fallers and frequent fallers met the defined criteria. Height and weight were collected for each subject prior to beginning any of the functional performance tests (Table 1). The study was approved by the Oregon State University Institutional Review Board and all subjects gave written informed consent.

Clinical Assessments of Mobility

Mobility was assessed by timing individuals over a series of gait and lower extremity power tests. Characteristic Gait, Maximum-wide Gait, Tandem Gait, Circular Gait, the Get Up and Go, and the Sit-to-Stand comprised the battery of gait measures. For the Characteristic Gait test, participants were asked to walk at their "normal" pace, such as they do when they get the mail or take a stroll, for a distance of 20 m. The average of two trials was used to represent characteristic walking speed. For the Maximum-wide Gait test, subjects straddled a 30.5-cm track and walked as quickly as possible without touching the track (Figure 1). This required that subjects maintain a wide stance for the entire distance. One contact with the track was acceptable, but more than one touch resulted in a mistrial. Circular Gait was performed on an S-shaped track having a width of 15.2 cm (Figure 2). Subjects had to maneuver the course requiring them to make one gradual turn to the left and one to the right. Because they had to keep their feet to the outer edges of the track, a crossover step was not required. Characteristic, Maximum-wide, and Circular Gait were completed over a distance of 20 m while the Tandem Gait was truncated to 10 m on the basis of pilot data demonstrating that most subjects could not complete the task over a 20-m distance. The Tandem Gait, Sit-to-Stand, and Get Up and Go tests are described elsewhere (13,14,15). For the gait tests, the fastest times from two trials were used in the analysis.

A stair climb was used to assess functional power. Subjects ascended a flight of three stairs as quickly as they could safely do so and were asked to avoid using the handrails if possible. Subjects were timed from the base of the stairs until the foot of the trailing leg was planted on the top stair. Each person com-

Figure 1. Wide Gait test.

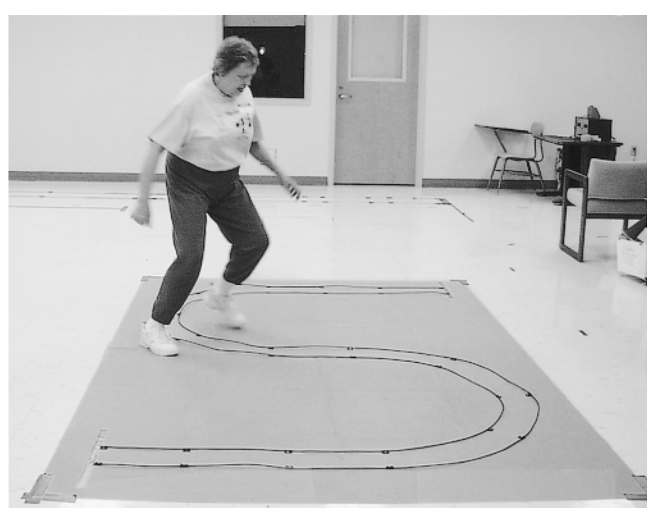

Figure 2. Circular Gait test.

Table 1. Means (± *SD*) for Age, Height, and Weight Described by Group and Gender

Variable	Nonfallers (n = 48) Mean	*SD*	One-time Fallers (n = 56) Mean	*SD*	Frequent Fallers (n = 53) Mean	*SD*	Total (n = 157) Mean	*SD*
Age (y)								
Females	74.74	5.32	78.5	5.1	77.48	5.32	77.06	5.42
Males	79.9	6.43	77.2	4.87	80.2	4.60	78.92	5.51
Total	75.93	5.94	78.27	5.03	77.74	5.28	77.37	5.46
Height (cm)†								
Females	161.54	5.42	158.37	6.6	158.83	5.55	159.43	6.01
Males	174.87	6.24	177.03	8.31	171.56	8.33	175.07	7.45
Total	164.61	7.93	161.71	9.94	160.03	6.88	162.02	8.54
Weight (kg)								
Females	62.98	9.31	66.25	11.50	68.95	13.64	66.32	11.95
Males	80.47	19.60	81.25	12.43	73.22	8.34	79.38	15.17
Total	66.99	14.26	68.93	12.93	69.35	13.23	68.48	13.40

†Wilks's Lambda for the effect of group on height was $p < .001$. Height was a covariate in subsequent analyses.

pleted two ascents beginning with the right leg and two beginning with the left leg. Subjects were timed only during the climbing phase and could descend the stairs using a handrail at their preferred pace. The fastest trial for each leg was used.

Laboratory Assessments of Strength and Power

Knee extension and hip abduction were assessed by isometric dynamometry. Subjects exerted maximal force against a handheld dynamometer (Model 01160, Lafayette Instrument Company, Lafayette, ID) until the operator observed the force reading at a plateau. Trials lasted approximately 5 seconds. The maximum values from three trials were used. Ankle plantar flexion, dorsiflexion, inversion, and eversion were assessed in a similar manner using equipment designed in our laboratory. Subjects were asked to exert maximal isometric force for approximately 5 seconds as the ankle dynamometer acquired peak torque values. The peak torque over four trials was used.

Leg extension power was assessed using a seated leg press (Nottingham Power Rig, Nottingham, UK). Subjects were asked to exert maximal force and velocity during hip extension. Participants completed nine trials for each leg to allow mastery of the task (16). The peak value for each leg was used.

Reliability

Reliability over all measures was conducted on 26 subjects. Intraclass correlations over the power variables ranged from .83 to .92 with the exception of the Sit-to-Stand task, which had a correlation coefficient of .58 and failed the test of nonrandomness. As such, the Sit-to-Stand was omitted from subsequent analyses. Reliability for leg extension power ranged from .86 to .92 for the right and left legs, respectively. This is consistent with previously reported data (16). The stair climb was reliable at .90 for the right leg and .83 for the left leg. Reliability values for the gait tests ranged from .68 to .93. Reliability values for strength variables ranged from .52 to .90.

Data Analysis

Multivariate analysis of covariance (MANCOVA) was used to determine differences between nonfallers, one-time fallers, and frequent fallers over the variables of interest. Stepwise discriminant function analysis was used to determine which of the significant variables discriminated best between groups. Based on the data from the MANCOVA and supported by the results from independent *t* tests, the three groups were collapsed into fallers and nonfallers. Validation of the predictors was carried out using a leave-one-out procedure.

Classification of Fallers and Nonfallers

On the basis of self-reported falls information and falls interviews, 48 individuals were categorized as nonfallers, 56 individuals were considered one-time fallers, and 53 individuals were frequent fallers. The frequent fallers experienced an average of 2.55 ± 1.05 falls over the 12 months prior to testing. The groups were similar with respect to age and weight. However, the nonfallers were significantly taller than the frequent fallers. Thus, height was used as a covariate in all subsequent group analyses. Chi-square analysis demonstrated that the overall proportions of males and females was similar between groups and that gender was independent of group membership (Pearson chi-square = .181). There were no differences over any of the strength, power, or mobility variables between men and women within groups.

Results

Results on the mobility tests exhibited a consistent positive skew. Thus, to correct for violations of assumptions associated with MANCOVA, scores on the gait tests were transformed using a natural logarithmic procedure. Using MANCOVA on the transformed data and controlling for height, nonfallers were significantly faster than both one-time fallers and frequent fallers ($p < .01$) during the Get Up and Go and faster than one-time fallers on the Tandem Gait ($p < .01$) (Table 2). There were no significant differences between groups for other mobility variables or for laboratory measures of strength and power. However, independent *t* tests indicated that one-time fallers were more similar to frequent fallers than to nonfallers over all variables.

Because the one-time fallers were similar to frequent fallers, the original three groups were collapsed into nonfallers and fallers for the discriminant function analysis. The variables selected for analysis were those determined to be different between groups by MANCOVA (Tandem Gait and Get Up and Go). Variables were entered into the analysis in a stepwise manner. The criteria for entry was $F < .05$, and the criteria to remove was $F > .100$. The Get Up and Go test discriminated between the fallers and nonfallers with a final Wilks's Lambda of .900 ($p < .001$). The Get Up and Go correctly classified 72.4% of fallers and nonfallers before crossvalidation and 71.2% of the cases after validation.

Discussion

Our first research question was whether frequent fallers differed from nonfallers and one-time fallers with respect to lower extremity strength and power, and functional mobility. We found that frequent fallers differed from both one-

Table 2. Means (± *SD*) for All Variables

Variable	Nonfallers (n = 48)	One-time Fallers (n = 56)	Frequent Fallers (n = 53)
Mobility tests[†]			
Characteristic	6.20 ± 1.209	6.87 ± 1.31	7.05 ± 1.27
Maximum-wide	5.35 ± 1.29	6.28 ± 1.51	6.21 ± 1.43
Tandem*	13.17 ± 1.51	17.30 ± 1.50	16.29 ± 1.57
Circular Gait	7.60 ± 1.28	8.77 ± 1.43	8.98 ± 1.37
Get Up and Go*	7.54 ± 1.21	8.91 ± 1.34	9.21 ± 1.31
Strength			
Knee extension (kg)	51.27 ± 15.7	43.99 ± 15.7	44.96 ± 11.0
Hip abduction (kg)	39.57 ± 9.7	35.89 ± 12.9	34.69 ± 9.1
Ankle dorsiflexion	46.34 ± 16.0	47.87 ± 18.1	42.93 ± 13.6
Ankle inversion	19.56 ± 8.1	19.78 ± 8.1	18.99 ± 7.9
Ankle eversion (ankle data in Newtons)	16.12 ± 6.4	15.86 ± 6.1	16.22 ± 5.72
Power			
Leg extension	221.8 ± 98.3	230.1 ± 98.3	234.8 ± 88.7
Stair climb (power in watts)	332.9 ± 92.0	307.1 ± 108.5	304.1 ± 107.3

*$p < .02$.

[†]Means for the mobility tests are presented as the anti-log of transformed data.

time fallers and nonfallers on the Get Up and Go test and differed only from one-time fallers on the Tandem Gait test. Because one-time fallers were similar to frequent fallers on all other measures, these two groups were collapsed for discriminant function analyses. Our second research question was to determine whether laboratory measures or mobility measures best discriminated between the two new groups (fallers and nonfallers). We found that the Get Up and Go, a test involving both lower extremity strength and power, and mobility, was the best predictor of whether an individual was a faller or a nonfaller.

Our study has several strengths. First, three distinct groups were evaluated. Other studies have examined differences in measures of strength and mobility in fallers and nonfallers (7,17,18), but few have conducted a three-group analysis consisting of nonfallers, one-time fallers, and frequent fallers. Second, our elderly population was homogenous with respect to age. Few studies have examined differences in physical performance measures between fallers and nonfallers without attributing at least some of the differences to age. In addition, both men and women were included in our study. Therefore, we are in a better position to generalize our findings to elderly fallers of both genders. Although falling is a significant problem for elderly women, men are also at risk (19).

Our study also has several limitations. As with any case-control study, there is a potential for unmeasured differences between cases and controls. However, the majority of our population was recruited from a falls surveillance database, all were independently dwelling, and none required caregivers. Furthermore, medication use was similar across groups. A second limitation is sample size. Statistical power is lower for the measures of lower extremity strength and power compared with the measures of gait. This may indicate a smaller effect size related to strength and power. It is also possible that the low reliability of the knee extension and hip abduction measures influenced variability, which likely affected statistical power. In addition, we were unable to use ankle data on eight subjects, all of whom were nonfallers.

We found that nonfallers performed better than both one-time fallers and frequent fallers on the Get Up and Go, a measure that was associated with both mobility and lower extremity power ($r = -.32$ to $r = .42$, $p < .001$). Furthermore, the Get Up and Go was the best variable for categorizing individuals based on falls status, with 72% of all subjects being correctly classified. These findings are consistent with previous research. There is only one other report using the Get Up and Go to discriminate fallers from nonfallers. In a study of community-dwelling women over 65 years of age, O'Brian and colleagues (20) reported that the Get Up and Go accurately categorized nonfallers 100% of the time, although it was less sensitive in identifying fallers (62%). However, they had only 13 fallers in their study. In our study, by contrast, the Get Up and Go accurately classified 98% of the fallers but was less sensitive in identifying nonfallers. Previous work indicates that medically stable individuals vary little in their score on the Get Up and Go over time (15). Thus, a poor performance on the Get Up and Go could reflect subtle changes to falls risk factors that contribute to a medically unstable profile, such as changes in functional level, chronic disease, and medication use. That the one-time fallers in our study performed similarly to the frequent fallers on the Get Up and Go and that both groups were significantly slower than nonfallers may indicate subtle changes in lower extremity strength, power, and mobility that simple tests measuring a single variable are unable to pick up.

Poor performance on the Tandem Gait test has been associated with increased falls risk (7). The results of our study support this finding. Nonfallers performed better than one-time fallers on the Tandem Gait ($p = .005$). Nonfallers were faster than frequent fallers by an average of 3 seconds and faster than the one-time fallers by over 4 seconds. These results were surprising. However, the frequent fallers required more attempts to achieve two error-free trials as compared with the nonfallers and required more assistance through encouragement and coaching in order to achieve the required number of trials. This likely explains the slightly better scores compared with one-time fallers and the fact that scores did not quite reach statistical significance compared with nonfallers. Chu and colleagues (7) found poor tandem gait performance to be the most significant predictor of falls followed by lower limb weakness in older hospital inpatients. Others have found poor tandem gait ability in community-dwelling elderly individuals to be associated with decreases in strength and balance (21,22). Thus, the Tandem Gait test seems a reasonable tool for identifying fallers, not only in frail hospital-bound elderly persons, but also in healthy, independent-living elderly individuals.

We found that one-time and frequent fallers were more similar across physical performance variables than were one-time fallers and nonfallers. This is contrary to previous reports (4,23). Focusing on falls rather than fallers, Nevitt and colleagues (4) found that one-time falls are less predictable than frequent falls, more likely to be associated with accidents and overwhelming incidents than frequent falls, and are therefore less indicative of those with a physiological predisposition to falling. However, 37% of their study population was between 60 and 69 years of age, and it is possible that many of the one-time fallers were younger, particularly given that age was reported as a risk factor for frequent falls. Under our definition of a fall, and with close review of the circumstances and characteristics of falls reported within our study population, we found that the characteristics of one-time falls were similar to the characteristics of frequent falls. In addition, one-time fallers were similar to frequent fallers with respect to both lower extremity strength and power and to measures of functional mobility.

To our surprise, lower extremity strength and power did not discriminate between fallers and nonfallers. Our findings for strength are consistent with those of Wooley and colleagues (18), who also utilized isometric measures and found no differences in strength between elderly fallers and nonfallers. However, they did not report reliability on their strength measures. In an attempt to incorporate measures easily utilized in a field setting, we chose an isometric dynamometer for the measurement of lower extremity strength. Our data show this to be unreliable for assessing lower extremity strength in an elderly population and, as such, may account for the lack of differences. Thus it is unclear whether the lack of significance is related to reliability or whether strength is not as important as mobility in discriminating between the nonfallers, one-time fallers, and frequent fallers in our sample. Among those who have examined lower extremity power in relation to falls, Whipple and colleagues (17) found that fallers had reduced knee extension and dorsiflexion power compared with nonfallers as measured with an isokinetic dynamometer. Our data reflect no differences between groups for lower extremity power. It is possible that sample size contributed to the lack of findings, but statistical power was adequate at .63. Thus, it is more likely that these measures do not discriminate well between nonfallers, one-time fallers, and frequent fallers.

After testing fallers and nonfallers on measures of mobility, strength, and power, we have identified the Get Up and Go as a practical, efficient method to identify most fallers. In addition, the fact that one-time fallers were similar to frequent fallers contradicts previous work and indicates that they may be exposed to a greater risk of falls and subsequent hip fracture (5). Given the sensitivity of the Get Up and Go to discriminate between elderly fallers and nonfallers and its association with lower extremity strength and power, fall prevention strategies should focus on improving lower extremity strength and power as well as functional mobility.

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