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Fall History and Associated Physical Performance Measures in Competitive Senior Athletes

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Topic Investigated: Physical performance measure outcomes most associated with falls in senior athletes.
Subjects: A total of 928 senior athletes.
Variables: Fall history, Single Leg Stance Eyes Open, Single Leg Stance Eyes Closed, Single Leg Stance on Foam, Functional Reach, Usual and Fast Gait Speed, Five Times Sit-to-Stand Test, and Grip Strength. Data were analyzed with logistic regression and receiver operating characteristic curve analyses.
Results and Conclusions: Combined failure, as determined by cut scores, on Single Leg Stance Eyes Closed and on Foam was most associated with a recent history of falls. Performance on the Five Times Sit-to-Stand Test was also highly associated.
Key words: Five Times Sit to Stand, functional reach, gait speed, grip strength, Senior Olympics, single leg stance

Falls continue to be a major health concern for older adults with an annual incidence of approximately 1 in 3,[1] leading to a risk of injury[2] and functional decline.[2,3] Physical Performance Measures (PPMs) are frequently used in the evaluation and screening of older adults, often to assess balance or determine fall risk.[4,5] Previous PPM studies investigating falls have focused on those already diagnosed with disease, those hospitalized or living in institutions, or the general community-dwelling population. Each of these populations has associated normative data and thresholds that must be used in the context of the population studied. However, a large and growing population of older adults is now participating in competitive sports. Growth in the 50+ age categories for marathons,[6] triathlons,[7] and other competitive events[8] has occurred in recent years. When tested, competitive senior athletes (SAs) have significantly outperformed community-dwelling norms on PPMs.[9-11] This is likely related to the predominance of sedentary behavior in the general population of older adults.[12]

The incidence of falls in the higher-functioning SA cohort is unknown, as is their performance on any standard measure of balance. The limited evidence that exists suggests that SAs have superior balance when compared with community dwellers[13,14] and indicates the need for more sensitive screening measures in this high-functioning population. Studying balance and fall trends in SAs could assist this thriving population in better health maintenance and persistence in their highly active lifestyle choices, thus preventing the known expense and health care burden associated with falls. The purpose of this study was to investigate the prevalence of falls in SAs and examine the relationships between PPM outcomes in SAs with and without a history of falls.

METHODS

Subjects

Subjects were recruited by posted advertisements at exhibit halls associated with the National Senior Games (NSG) where the screening took place. Subjects were SAs aged 50 years or older who volunteered to participate in a larger health screen during the 2011 and 2013 NSG. Participation in the NSG required all athletes to have qualified in their sport at the state level. All registered NSG athletes were eligible to participate in the screen. Nine hundred twenty eight athletes were screened, 394 (42.5%) were male and 530 (57.1%) were female with 4 athletes not identifying a gender. Mean age of those screened was 68.12 (9.22). Senior athletes reported spending an average of 5.1 hours (SD: 3.9) each week on cardiovascular exercise and 1.0 hour (SD: 1.5) each week on strength training. Each participant signed a written informed consent form before participating. This study was approved by the local institutional review board prior to any data collection.

Self-reported falls

Self-reported falls are a common practice in fall risk screening, though respondents tend to underreport rather than overreport fall rates.[15,16]

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All participants answered the question, "Have you had a fall in the past twelve months?" Athletes with a positive response were further asked to report how many times they had fallen in the past 12 months.

Single Leg Stance

Single Leg Stance Eyes Open (SLS-EO) is supported as a valid screening tool for prediction of falls in community-dwelling elders[17-20] and is often the choice of practicing physical therapists.[21] Single Leg Stance Eyes Open and Single Leg Stance Eyes Closed (SLS-EC) have been shown to have high interrater reliability when using the best of 3 trials.[18,22] Hurvitz et al[5] reported 30 seconds to be the optimal cutoff for SLS-EO to determine risk for multiple falls in a population of community-dwelling older adults.[5] No thresholds for SLS-EC or Single Leg Stance on Foam (SLS-F) have been established in the literature, to the knowledge of these authors.

Single Leg Stance Eyes Open

Participants donned a gait belt and were tested on their preferred foot with shoes off, arms crossed over their chest, and opposite leg lifted and not in contact with the stance leg. Timing was started when the opposite leg was lifted and stopped at 30 seconds or when the participants touched their lifted leg to the ground, shifted their stance foot, uncrossed their arms, pressed their lifted leg to the stance leg, or otherwise supported their balance externally. Times were recorded as the best of 3 trials to the nearest hundredth of a second.

Single Leg Stance Eyes Closed

Participants were tested and scored in a manner identical to SLS-EO with the addition that timing was not started until the participant was in single leg stance with both eyes closed. Timing was stopped additionally if the eyes fluttered or opened.

Single Leg Stance Foam

Participants were tested and scored in a manner identical to SLS-EO with the addition that timing was not started until the participant was in single leg stance on a 2" foam pad.

Functional Reach Test

Functional reach, commonly used in clinical settings, is a valid measure of fall risk when used in the community-dwelling elderly and has high interrater[23] and test-retest[24] reliability.

Functional reach in centimeters was measured with a meter stick as per the original description by Duncan et al.[23] Participants were instructed to reach with their dominant arm, hand closed in a fist, as far as possible without losing their balance, taking a step or touching the wall. The average of 3 reaches was used for data analysis.

Gait Speed

Usual Gait Speed (UGS) is supported in the literature as a valid means of predicting falls[25,26] and correlates with mortality,[27-29] disability,[30,31] and several other negative health outcomes.[32] Senior athletes have already demonstrated greater Fast Gait Speed (FGS)[11] than less active older adults, and current literature encourages the use of FGS in the testing of high-functioning seniors.[33] Both UGS[34,35] and FGS[34] are supported as reliable PPMs.

Usual Gait Speed

Participants' UGS in meters per second was measured over a 10-m walkway with 5 m on each end for acceleration and deceleration. Participants were asked to walk at their normal speed, as if they were walking to the mailbox or walking in a mall. Researchers followed behind the athlete with a stopwatch and timed the central 10 m of the walkway. Speed was recorded as meters per second to the nearest hundredth of a second.

Fast Gait Speed

Fast Gait Speed was measured on the same walkway as UGS and participants were instructed to walk as fast as they could without running. Timing and scoring was otherwise identical to UGS.

Five Times Sit-to-Stand Test

Senior athletes were previously reported as scoring better on the Five Times Sit-to-Stand Test (FTSST) than community-dwelling norms.[9] The FTSST is supported as a valid PPM for evaluating balance,[36] strength,[37] and functional mobility.[37] This measure has also been identified as a predictor of functional mobility,[38] injuries,[39] and multiple falls[40,41] in community dwellers. High test-retest,[37,42,43] intrarater[43] and interrater[42,43] reliability further supports this test as a clinically sound PPM.

Five Times Sit-to-Stand Test instructions for athletes required them to rise and sit from a standard armless chair (43 cm) 5 times as quickly as possible with arms crossed over their chest. Timing was started when the researcher said "go" and stopped when the athlete sat after the fifth stand.

Grip Strength

Grip strength (GpS) has been found to assist in the identification of fallers in healthy older adults[44,45] and as a means to predict functional limitations.[46] It is supported as a valid measure of functional mobility, and strength, with high test-retest reliability.[37]

Grip strength was collected as the mean of 3 trials for right and left hands using a hydraulic hand grip dynamometer. Participants were seated with their elbow by their side and flexed to 90° with their wrist in a neutral position. To capture each participant's strongest grip, the hand with the higher GpS mean was utilized for analysis. Because

GpS does differ significantly by gender, results of male and female GpS were analyzed separately.

DATA ANALYSIS

Point biserial correlations were used to initially explore the relationships between each PPM and the report of a fall or multiple falls in the previous 12 months. Collinearity between several of the screening measures prevented the use of a single omnibus logistic regression for data analysis. Instead, a separate regression and receiver operating characteristic curve analysis was used for each screening measure. The Youden method was used to find the optimal cutoff for each measure and for each group: fallers and multiple fallers. A new variable, Balance Fail (BF) was created to indicate SAs who failed the SLS-EC and SLS-F measures on the basis of the optimal cutoffs identified. This variable was further tested with logistic regression to improve screen interpretation. SAS version 9.3 was used for all data analyses.

RESULTS

Ninety eight (10.6%) SAs reported a fall in the past 12 months and 28 (3%) reported more than 1 fall in the same time frame. Mean results of athlete performance on each PPM are presented in Table 1. Participation rates varied on each PPM as not all measures were offered at the 2011 NSG, and some athletes chose not to complete all PPMs due to time constraints with their competition schedules. Point biserial correlations, shown in Table 2, demonstrate overall weak relationships between these PPMs and fall rates. Measures showing small, yet significant, relationships for falls were SLS-EC, SLS-F, Male GpS, UGS, and FTSST. Measures showing significant relationships for multiple falls were SLS-EO, SLS-F, and FTSST. The only measures with a significant correlation for both fallers and

TABLE 1 Mean Score and Standard Deviation by Screening Measure

PPM	N	Mean (SD)
SLS-EO (s)	915	24.31 (9.52)
SLS-EC (s)	822	7.53 (6.87)
SLS-F (s)	910	15.19 (10.92)
FR (cm)	748	32.85 (6.54)
Male GpS (kg)	394	45.56 (9.38)
Female GpS (kg)	530	31.07 (6.58)
UGS (m/s)	917	1.42 (0.22)
FGS (m/s)	701	2.12 (0.43)
FTSST (s)	921	7.67 (2.45)

Abbreviations: Female GpS, Female Grip Strength; FGS, Fast Gait Speed; FR, Functional Reach; FTSST, Five Times Sit-to-Stand Test; Male GpS, Male Grip Strength; PPM, Physical Performance Measures; SLS-EC, Single Leg Stance Eyes Closed; SLS-EO, Single Leg Stance Eyes Open; SLS-F, Single Leg Stance on Foam; UGS, Usual Gait Speed.

TABLE 2 Point Biserial Correlations Between Screening Measures and Fall History

	r_{pb} (*P*)								
	SLS-EO	SLS-EC	SLS-F	FR	Male GpS	Female GpS	UGS	FGS	FTSST
Fall	−0.042 (.20)	−0.086[a] (.01)	−0.12[a] (<.001)	−0.03 (.40)	−0.139[a] (.006)	−0.056 (.20)	−0.08[a] (.02)	−0.05 (.18)	0.19[a] (<.0001)
Multi	−0.07[a] (<.05)	−0.03 (.41)	−0.08 (.02)[a]	−0.02 (.66)	−0.024 (.64)	−0.034 (.438)	−0.05 (.16)	0.008 (.83)	0.07[a] (.02)

Abbreviations: Female GpS, Female Grip Strength; FGS, Fast Gait Speed; FR, Functional Reach; FTSST, Five Times Sit-to-Stand Test; Male GpS, Male Grip Strength; SLS-EC, Single Leg Stance Eyes Closed; SLS-EO, Single Leg Stance Eyes Open; SLS-F, Single Leg Stance on Foam; UGS, Usual Gait Speed.

[a]*Significant with P < .05.*

TABLE 3 Logistic Regression by Screening Measure

	OR (*P*)		AUC		Goal Score	
	Fall	Multifall	Fall	Multifall	Fall	Multifall
SLS-EC	0.946[a] (.017)	0.969 (.421)	0.586	0.572	5.51 s	4.14 s
SLS-F	0.964[a] (.0006)	0.955 (.023)	0.609	0.639	14.27 s	12.58 s
BF	2.30[a] (.0001)	2.88[a] (.0001)	0.602	0.628	NA	NA
UGS	0.293[a] (.018)	0.267 (.151)	0.568	0.601	1.46 m/s	1.31 m/s
FGS	0.653 (.181)	1.12 (.838)	NA	0.509	NA	NA
FTSST	1.25[a] (.0001)	1.095 (.040)	0.652	0.635	8.21 s	7.57 s
Male GpS	0.939[a] (.007)	0.977 (.637)	0.658	0.583	NA	NA
Female GpS	0.974 (.199)	0.973 (.434)	NA	0.537	NA	NA

Abbreviations: AUC, area under curve; BF, Balance Fail; Fall, Fell at least once in the past year; Female GpS, Female Grip Strength; FGS, Fast Gait Speed; FTSST, Five Times Sit-to-Stand Test; Male-GpS, Male Grip Strength; Multifall, Fell more than once in the past year; NA, not applicable; OR, odds ratio; SLS-EC, Single Leg Stance Eyes Closed; SLS-F, Single Leg Stance on Foam; UGS, Usual Gait Speed.

[a]*Significant with P < .05.*

multifallers were SLS-F and the FTSST. Measures showing no significant relationship for either group were the functional reach, Female GpS, and FGS.

Results of the individual logistic regressions identified the following tests as significantly associated with fall history: Single Leg Stance Eyes Closed ($P = .02$), SLS-F ($P < .001$), FTSST ($P < .0001$), and the new variable BF ($P < .0001$). Results are presented in Table 3. Odd ratios (ORs) for each of the preceding measures suggest that PPMs most associated with falling are BF with an OR of 2.38 and the FTSST with an OR of 1.25. Ideal cut-points for these measures can also be found in Table 3, with BF defined as an athlete who could not achieve both SLS-EC for at least 5.51 seconds and SLS-F for at least 14.27 seconds. Thus, SAs who failed both SLS-EC and SLS-F were more than twice as likely to have fallen in the past year when compared with athletes who achieved or surpassed the identified cut-points on these measures. Senior athletes who completed the FTSST in 8.21 seconds or less were more likely to be nonfallers as were SAs who demonstrated a UGS of at least 1.46 m/s. Those identified with a history of multiple falls demonstrated UGSs less than 1.31 m/s. Male GpS appears to be associated with falls in this population (OR = 0.939, $P = .007$), but a similar relationship is not apparent for female GpS.

DISCUSSION

Senior athletes demonstrate a considerably lower incidence of falls than their community-dwelling counterparts, supporting previous findings that they maintain better overall balance.[13,14] Recent investigation into the impact of higher intensity physical activity supports the premise that exercise can improve higher-level balance abilities[47] and may very well explain this low incidence.

This population, however, is not immune to the problem of falls. With more than 10% of our studied athletes reporting a fall, the health risks posed to this cohort cannot be ignored. Because of their participation in vigorous sport competition, many assumptions may be made regarding their overall level of fitness without a true assessment of balance or fall risk, especially when considering their activity level. While this population does prove to have superior balance, they can still benefit from regular balance and fall-risk screening, as the impact and cost of even 1 fall could result in loss of participation ability, permanent disability, or hospitalization. In fact, these higher-functioning seniors may take greater risks in their day-to-day lives[48] and thus risk falls performing higher-level activities. While this has not been directly studied in SAs, one could simply address the demands of their immediate sporting events such as triathlons, tennis, and basketball, to identify their unique and self-directed challenges to balance. Many of the SAs screened for this study reported surprise at their balance limitations as they had never had their balance tested. Without PPM guidelines appropriate for this cohort, their relative balance impairments and fall risks could easily go undetected. Screening this group with more rigorous and relevant criteria is necessary to determine those who could benefit from increased awareness or actual interventions for fall prevention.

This is the first study, to our knowledge, to investigate falls and consider optimal thresholds for PPMs relating to falls in the SA population. Considering that clinical recommendations for treating this population[47] already include the use of more challenging activities and varied surfaces, such as foam, it appears reasonable to include evaluation at a similarly advanced level, which has been suggested by other authors.[33]

Although the FTSST has been reported as a predictor of falls in community dwellers,[41] we were surprised at its persistent ability to predict falls in even this higher-functioning population. Perhaps the element of strength in this measure reflects the need for more than raw balance in an individual's ability to prevent falls. Recent studies[49] have supported lower extremity strength as a better predictor of falls than gait speed. This appears to be consistent with our findings that gait speed was not strongly associated with falls in SAs. We are not able to explain the poor ability of FGS to assist in fall prediction. It could be that FGS is useful in this population, but for studying a different construct than balance or falls. Previous findings even suggest that faster walking ultimately becomes unsafe and further increases the risk of falling.[50] Addressing FGS and its relationship to other measures of health and physical performance is encouraged.

The relationship seen in our data between high GpS in men and decreased falls is supported by previous work, which found better balance in men, but not in women, with higher GpS.[51] This makes it difficult to apply GpS as a measure associated with falls in all SAs. These findings, however, merit further investigation into the relationship between strength, gender, and balance.

LIMITATIONS

Our main limitation in this study was the utilization of self-report data to categorize fall history status. This type of retrospective reporting is known to contain error with a tendency to underreport falls.[15,16] Cut scores determined from this population could, therefore, be more lenient than necessary to truly associate with nonfallers. Furthermore, this retrospective approach may be defining the performance of individuals who are impaired as a result of their fall rather than demonstrating their abilities before they fell. Further research to examine these findings in a prospective study of falls in SAs is warranted.

Another limitation involved the location of our testing. Physical Performance Measures were tested in busy exhibit halls and although the testing was performed in an area protected from foot traffic, the environment could have played a role in distracting participants or motivating them to perform for others present. Our location also allowed athletes to volunteer for this screen on their own timeline. They may have been at various stages of preparing to compete or recovering from competition when they were tested, which could have resulted in distraction or fatigue.

Some outcomes found in this study could also be the result of our sampling method. The SAs who voluntarily stopped to perform the screen may have done so because of higher confidence in their balance or, conversely, because of concerns regarding their balance. It may also be that those with poorer balance or a history of falling chose not to compete in the NSG. Caution should be used when considering these results in relation to other populations of older adults as these findings are specific to NSG athletes.

Finally, the very low (3%) incidence of multiple falls in this population is encouraging but makes generalizations regarding multiple fallers even in this population more difficult. When assessing SAs, clinicians are encouraged to focus on the risk of any falls rather than multiple fallers.

CONCLUSION

In this unique population of competitive SAs, the incidence of falls is low but still persists. Senior athletes with a history of falling demonstrate poorer performance on SLS-EC, SLS-F, and the FTSST than their peers who report no fall history. Combined performance of less than 5.51 seconds on SLS-EC and less than 14.27 seconds on SLS-F appears to be appropriately challenging and strongly associated with SAs who report a known fall history. Five Times Sit-to-Stand Test scores of more than 8.21 seconds are also highly related to fall history in this cohort.

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