# Senior Sway: Using a Mobile Application to Measure Fall Risk

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## ABSTRACT

**Background and Purpose:** The Senior Sway mobile application uses the iPhone/iPad gyroscope to assess postural sway and motion reaction time. Impairment in postural sway and motion reaction time have the potential to increase risk for future falls. Senior Sway thereby has the potential to provide a quick, easy to use, objective measure for predicting falls in older adults. The purpose of this study was to evaluate the feasibility of the Senior Sway mobile application and its associations with fall risk in community-dwelling older adults.
**Methods:** Adults older than 62 years were recruited from senior centers and community events. Descriptive and bivariate statistics were used to examine feasibility on the basis of enrollment, time required, satisfaction with application, and association with fall risk.
**Results and Discussion:** Fifty-seven adults were recruited. Use of the Senior Sway mobile application was feasible. Ninety-one percent said that they liked the application and reported length of time of assessment was "just right." The average Senior Sway score was 64.0 (range: 47.8-84.0), which was significantly associated with the 30-second sit-to-stand test. In addition, the motor reaction time score was associated with the Timed Up and Go.
**Conclusions:** Senior Sway is a promising application to improve identification of adults at risk for falls and need for rehabilitation but warrants further research.
**Key Words:** balance, falls, function/mobility, measurement, technology

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## INTRODUCTION

One in 4 older adults falls each year, and less than half of older adults discuss previous falls with their health care providers.[1,2] Falls (anytime a person comes to the floor inadvertently) remain the leading cause of fatal and nonfatal injuries in the United States. In 2014, 2.8 million nonfatal falls were treated in the emergency department of those 30% were hospitalized with severe injuries including traumatic brain injury and fractures.[3] Older adults, 75 years of age and older, are 4 to 5 times more likely to be removed from the community and institutionalized after a fall.[4,5] Furthermore, many who fall develop a fear of falling, even if the fall was not serious, and tend to reduce their engagement in daily tasks and time performing physical activity, limiting their overall fitness and mobility that can increase their risk for future falls.[6-8]

Standard predictors of fall risk include a limited functional ability in both activities of daily living (ADLs) and instrumental activities of daily living (IADL), decreased sensorimotor function, poor vision, reduced postural stability, and slower and less effective balance responses.[1,9,10] However, most of these predictors are not typically assessed in a general primary care clinic.[11] Moreover, the need for interventions that have been shown to be effective in decreasing fall risk, including physical and occupational therapy, may not be identified in traditional primary care clinics until after an older adult sustains a fall. Research supporting quick, easy-to-use, objective, and effective ways to examine fall risk is necessitated to identify people at risk for falling, which in turn may promote referral to physical or occupational therapy to decrease their fall risk.

Sway Balance is a Food and Drug Administration–approved medical application that uses the iPhone/iPad gyroscope to determine postural sway and visual-motion reaction time with standardized scoring (see Figures 1 and 2). The original Sway Balance mobile application was designed to detect abnormal postural sway and reaction time with athletes after a concussion, because they may suffer from balance issues postinjury.[12] The application has been shown to be more sensitive, less cumbersome, and more feasible than traditional balance assessments, such as the Balance Master and the Balance Error Scoring System assessment.[13,14] Other studies have utilized the iPhone/iPad gyroscope to measure postural sway without adding in the application's measure of visual-motion reaction time.[15] The aims of this study are therefore 2-fold: (1) to determine the feasibility of Senior Sway based on the ease of use and participant-rated satisfaction and length of assessment ("too long," "too short," or "just right") and (2) to examine the associations between the Senior Sway scores and traditional measures of fall risk. For purposes of this study, we refer to the application as Senior Sway as it differs from the Sway Balance in its protocol.

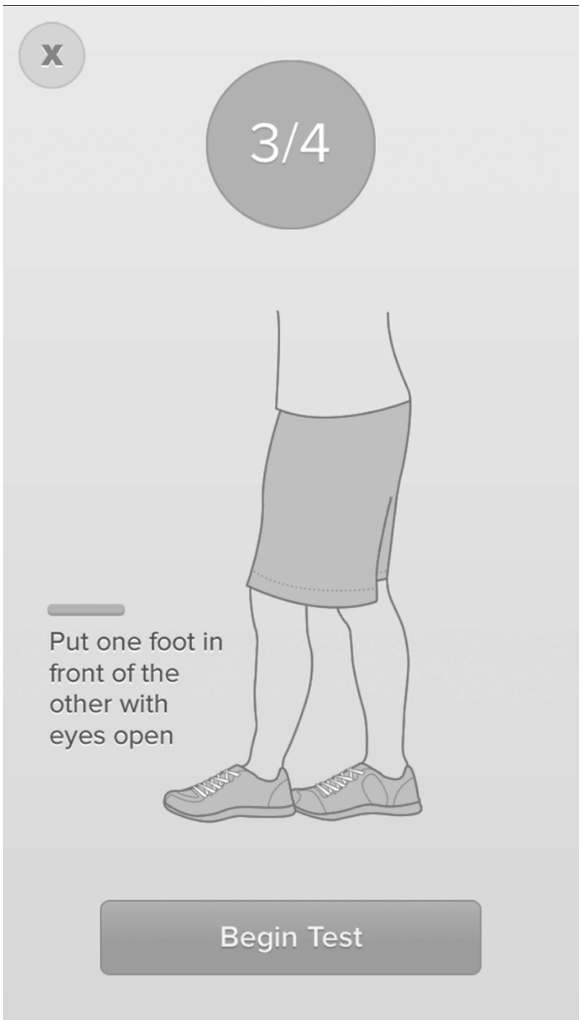


**Figure 1.** Instructions for tandem stance in Senior Sway mobile application.


**Figure 2.** Instructions seen by users to start Senior Sway mobile application.

## METHODS

Adults 62 years of age and older were recruited from senior centers and within community health fairs and fall-risk specific events, yielding a unique mix of adults who lived independently, within an assistive living facility with and without skilled nursing needs. According to the World Confederation for Physical Therapy, the term "older adults" is defined between 60 and 65 years of age in high-resourced countries, and therefore older adults 62 years of age and older were included.[16] Recruitment took place from August to November of 2015. Participants were included if they were able to walk with or without an assistive device, 62 years of age or older, and were able to speak and read English (all Senior Sway instructions are in English). Participants were excluded only if they could not walk. All participants were required to sign consent before enrolling. This study was approved by the Institutional Review Board at The University of North Carolina at Chapel Hill (IRB # 15-1660). We initially planned to recruit 40 participants but due to heightened interest, we expanded our sample to include all adults who wanted to participate and met our inclusion criteria. Participants were asked their age and sex and we recorded the setting in which the assessment occurred. Senior Sway took between 10 and 15 minutes to complete a baseline assessment. As suggested by the developers, participants completed the entire sway assessment 3 times in a row to produce an average score.

The primary objective was to examine the feasibility on the basis of the rate of enrollment/participation, participant-rated satisfaction, and length of assessment. The cutoffs for feasibility were predefi ned as follows: 60% participation/enrollment and a majority (>50%) stating the time it takes to conduct the assessment was "just right," indicating not too long or short.[17] We also asked participants whether they needed assistance as "Did you need help with Sway Balance application?" with answers "Yes" and "No" and if participants answered yes, they were then asked whether they needed "a lot" or "a little" help with the application itself. This help included following directions on the iPad and with physical support while performing the balance assessments.

The secondary objective was to examine associations between the Senior Sway results and traditional measures of fall risk. Traditional measures include the following: history of previous falls; the Timed Up and Go (TUG) time,[18] Centers for Disease Control and Prevention (CDC) Fall risk assessment, a part of the Stopping Elderly Accidents, Deaths and Injuries initiative for health care providers 4-stage static standing balance assessment,[19] and the 30-second sit-to-stand test lower extremity endurance test.[20] In addition, we examined the association of Senior Sway results with patient-reported IADL and functional status, which were measured by the Older Adult Resource Scale IADL section,[21-26] and the 1-question Patient-Generated Subjective Global Assessment-Activities and Function (PG-SGA-AF).[27-31]

The Senior Sway mobile application includes 2 tests—the CDC fall risk assessment and a visual-motion reaction time assessment. The CDC fall risk measure asks adults to stand in 4 different stances for 10 seconds each stance: feet together, feet staggered, tandem, and with 1 foot raised. During our assessment, participants were able to choose which foot to place forward in tandem and which foot to raise. If an adult is unable to hold tandem for 10 seconds, he or she is at risk for falling.[32] Senior Sway uses the internal gyroscope in the iPhone/iPad to measure postural sway while completing these 4-stage static standing stances with eyes open and iPad held tightly by both hands at chest level. An iPad was used for each of the assessments. The CDC fall risk assessment is followed by the visual-motion reaction time measure. For this measure, the iPad screen turns white, then yellow/orange. The participant was instructed to shake the iPad when the color changes, and Senior Sway assesses the amount of time it takes to react. From these assessments, the application then creates multiple scores.

For this study, we used 3 of those scores—a Senior Sway total score (combined average of all 4 stages of static balance plus the visual-motion reaction score), test subscores including a postural sway score for tandem only, and the visual-motion reaction score. We analyzed the tandem score as an independent score because being unable to hold tandem stance for 10 seconds delineates fall risk per the CDC fall risk assessment.[32] When completing the Senior Sway assessment, a baseline total score is created by completing the full assessment 3 times. While holding the smartphone to the chest, thoracic sway was monitored by device acceleration measured through the low-powered microelectromechanical system accelerometer within the iPad. Proprietary algorithms were recorded from each 10-second balance test to evaluate overall postural sway and visual-motion test in a combined and separate score. All scores were transformed to a score from 0 to 100. Scores closer to 100 represent better postural sway, faster reaction times, and hypothesized lower fall risk.

Traditional fall risk prediction and functional status measures were also used to address our second objective. The TUG assessment is a well validated measure of fall risk in older adults. This assessment asks participants to stand from a chair, walk 3 m at a normal pace, turn around, and return to sitting. If community-dwelling adults take longer than 11 seconds to complete this task, they are considered at risk for falling.[33,34] The 30-second sit-to-stand test asks adults to go from sitting to standing as many times as they possibly can within 30 seconds. Depending on age and sex, adults can be at risk for falling if they are unable to perform a certain number of completions of sit to stand, ranging from less than 4 (for women aged 90-94 years) to 14 (men in 60s), with higher scores indicating more sit/stands in a 30-second interval.[35] In addition, participants were asked how many times they have fallen in the last 6 months, as reporting of previous falls can predict future elevated risk of falling. Instrumental activities of daily living, for example, money management, home care, and using the telephone were assessed using the Older Adult Resource Scale Instrumental Activities of Daily Living section.[26,36] This IADL assessment is used commonly in geriatric assessments and consists of 7 items rated on 3-point scale asking the level of assistance needed to complete IADL with scores ranging from 0 to 14, 14 meaning they are completely independent on all IADL tasks.[36] This subsection of the Older Adult Resource Scale has been used extensively in older adults[23-26] and is recommended by the International Society of Geriatric Oncology.[22] Finally, we asked participants about their global activities and function using a single item, the PG-SGA-AF, which has respondents rate their level of daily activity for the last month from 0 to 4, in which "4" is bed bound and "0" is normal with no restrictions.[27] In post hoc analysis, we created a dichotomous composite indicator for falls risk and tested to see whether it related to Senior Sway total, tandem, or visual-motion reaction scores. The composite factor consisted of prolonged TUG, previous falls, reduced 30-second sit-to-stand test, and impaired IADL.

Descriptive statistics were used to describe the sample and determine feasibility. Bivariable analyses were completed to examine associations between Senior Sway scores and fall risk and functional status measurements. Post hoc analyses were used in dividing participants into 2 groups based on if they displayed any (≥1) or no fall risk factors based on the traditional measures of falls (TUG, previous falls, 30-second sit-to-stand test, IADL, PG- SGA-AF). For analyses, TUG (<11 vs ≥11), previous falls (yes vs no), IADL (14 vs <14), PG-SGA-AF (normal vs any limitation), and 30-second sit to stand test[18] were transformed to dichotomous variables, and Senior Sway scores were compared using nonparametric Wilcoxon rank sum tests. Spearman correlation coefficients were used to evaluate the correlation between Senior Sway scores and the continuous versions of TUG and 30-second sit-to-stand test score. For this study, we consider *P* values less than .05 as significant. Analyses were conducted using SAS statistical software v9.4 (Cary, North Carolina).

## RESULTS

For our primary objective, we enrolled 57 out of the targeted 40 due to heightened interest in study. Average age was 79 years (range: 62-96 years) and 70% (n = 40) were female and 30% (n = 17) were male. Ninety-one percent said that they liked the application and 91% reported that the length of time to take the assessment was "just right." Seventy percent said that they would use the application at home. These results demonstrate the feasibility of using Senior Sway with older adults based on our enrollment and positive reports from participants regarding time and overall satisfaction with the application (see Table 1). However, most participants needed at least some assistance with the balance assessments and/or the application: 56% needed a little help and 11% needed a lot of help. The question about needing help was not specific to the mobile application—it could also imply completing the questionnaire forms and/or maintaining balance during use of the assessment.

For secondary objectives, we evaluated the association of our generated 0 to 100 Senior Sway scores with typical fall risk assessments (TUG, 30-second sit to stand test, fallen in last 6 months, PG-SGA-AF, and IADL) as dichotomous variables. The average postural sway score for tandem only was 88 with a range of 33.3 to 99.5. The other subscore, visual-motion reaction, had an average of 47, with a range of 14.4 to 96.4. The average total Senior Sway score was 64.0, with a range of 47.8 to 84.0. Participants had an average TUG score of 11.3 with a range of 4 to 27, and 46% scored with prolonged scores above 11 seconds and were thus deemed at risk (see Table 2). Sixteen percent of participants reported that they had fallen in the last 6 months.

The total Senior Sway scores and average tandem were not significantly associated with TUG scores. However, the visual-motion reaction score was significantly associated with TUG scores of 11 or more ($P = .04$). Higher 30-second sit-to-stand test scores were correlated with the higher total Senior Sway scores ($P = .06$) and with the higher visual-motion reaction scores ($P = .02$) but were not correlated with tandem-only scores ($P =. 9$). Total Senior Sway scores, average tandem stance scores, and visual-motion reaction time were not significantly associated with reports of previous falls, above average 30-second sit-to-stand test scores, PG-SGA-AF scores, or IADL scores.

Continuous TUG scores were significantly negatively correlated with total Senior Sway scores ($r_s = -0.28$, $P = .03$) and visual-motion reaction score ($r_s = -0.30$, $P = .02$). The 30-second sit-to-stand test was not correlated with total sway score or tandem ($r_s = 0.19, -0.04$, $P = .15, .77$). However, it was significantly positively correlated with the higher visual-motion reaction scores ($r_s = 0.29$, $P = .05$) (Table 3).

**Table 1. Participant-Reported Satisfaction of the Senior Sway Mobile Application**

| Participant-Reported Satisfaction Items | n | % |
|---|---|---|
| Liked Sway Application?[a] | | |
| No | 4 | 7 |
| Yes | 52 | 91 |
| Need any help with Sway? | | |
| No | 16 | 28 |
| A little | 32 | 56 |
| Some | 1 | 2 |
| A lot | 6 | 11 |
| Would/could you use this at home? | | |
| No | 14 | 25 |
| Yes | 39 | 68 |

[a]1 missing.

**Table 2. Measures of Physical Health, Activities of Daily Living, and Fall Risk**

| Measures of Fall Risk | n | % |
|---|---|---|
| Timed Up and Go | | Range (5-40) |
| At risk (≥11 s) | 26 | 46 |
| Previous falls | | Range (0 -6) |
| None | 47 | 82 |
| 1 + | 9 | 16 |
| 30-Second Sit to Stand test | | Range (4 -27) |
| At risk | 11 | 19 |
| PG-SGA-AF | | |
| Normal no limitations | 41 | 72 |
| Fairly normal | 13 | 23 |
| In bed, at least half the day | 2 | 4 |
| Bed bound | 0 | 0 |
| OARS IADL | | Range (7-14) |
| At risk (<14) | 11 | 19 |
| Fall Risk compilation score[a,b] | | |
| At risk | 40 | 57 |

Abbreviations: IADL, Instrumental Activities of Daily Living; OARS, Older Adult Resource Scale; PG-SGA-AF, Patient-Generated Subjective Global Assessment-Activities and Function.
[a]Fall risk compilation score based on any risk factor: TUG, previous falls, 30-second sit to stand test, PG- SGA-AF.
[b]Higher scores indicate less postural sway and faster visual reaction time.

**Table 3. Continuous Variables Relationship to Senior Sway Scores[a]**

| | Senior Sway Total, $r_s$ (*P*) | Tandem, $r_s$ (*P*) | Visual Motion Reaction Time, $r_s$ (*P*) |
|---|---|---|---|
| TUG | −0.28 (.03)[b] | 0.02 (.90) | −0.30 (.02)[b] |
| 30-second sit to stand test | 0.19 (.15) | −0.04 (.77) | 0.29 (.02)[b] |

Abbreviation: TUG, Timed Up and Go.
[a]Senior Sway Scores include Senior Sway total, tandem, and visual-motion reaction time.
[b]Significant at $P \leq .05$.

In post hoc analyses, we divided participants into 2 groups based on whether they displayed any or no risk factors based on the traditional measures of falls (TUG, previous falls, 30-second sit-to-stand test, IADL, fairly normal score, or less ability on the PG-SGA-AF); 40 (70%) had at least 1 risk factor and the remaining 17 (30%) had none. Median scores were 67.2 for those with no risk factors, compared with 62.5 for those with 1 or more. This composite indicator did relate to Senior Sway score ($P = .03$), but not tandem, or visual-motion reaction scores ($P = .9$, .2), respectively. Total sway score was normally distributed, and in a multivariable linear regression model controlling for sex and age, this difference remained statistically signifi cant (mean difference of 3.9 between groups, SE 1.9, *t* value: 2.03, $P = .05$).

## DISCUSSION

This study demonstrates the feasibility of using the Senior Sway application with older adults living in the community. Senior Sway was well liked, and a majority of participants indicated that they would use the Senior Sway application at home. Older adults use technology to improve health care, with a little education and minimal support.[37] With newer, easier-to-use platforms and continued experience with technology, older adults' use of technology for their health will become more routine. Recognizing the complexity of identifying fall risk in community-dwelling older adults, the use of novel technology has potential to bring objective assessment to community clinics to increase identifi cation of adults at risk for falling.

This mobile assessment would not replace one's experience with a health care provider, which could be considered a negative use of technology for some older adults[38] but instead used as an additional tool within the clinic (either by providers or by assistants during intake) to asses fall risk and potentially determine need for specialized services to deliver multidisciplinary fall prevention interventions, for example, but not limited to, occupational and physical therapy. This is not a substitute for standard performance-based measures and documentation of fear of falling but is considered a screening tool to be used in general medicine clinics to determine potential need for services. Both occupational therapy and physical therapy have been shown to be effective in decreasing falls.[39,40] Falling can be detrimental to quality of life and life satisfaction in the long term and, therefore, it is imperative to identify adults at risk to provide intervention to decrease fall risk.[41]

In previous research, accelerometers have been shown to reliably and validly measure postural sway.[14,42] By measuring sway on a mobile device an easier, quicker, cheap version of balance plate evaluations is provided. Senior Sway has the potential to be a more portable measure of postural sway and fall risk, although not as detailed and specific as a full balance plate assessment.

This study showed an association between 30-second sit to stand test and the postural sway assessment in Senior Sway and correlations test between the visual-motion reaction component and TUG. In a different sample and study, Senior Sway was used with 57 middle-old aged community-living adults, and the association of Senior Sway scores with the Berg Balance Assessment and the Activities-Specific Balance Confidence Scale were examined.[43] This study focused on the measurement of postural sway and did not include the visual reaction test. Vincenzo et al[43] found results similar to ours that Senior Sway scores were unable to discriminate between those who had reported previous falls and those who did not. However, we believed that the Senior Sway test with the addition of the visual-motion reaction added essential information about fall risk that is not included in a measure of static postural sway only,[11] and we were able to demonstrate its correlation to 30-second sit-to-stand test. Furthermore, because results indicated that visual-motion reaction was associated with fall risk, this reaction time may be more important to measure separately in future research.

Recently, researchers found that a combination of head position, standing surface, and postural control was key to determining risk of falling.[44] Pociask et al[44] suggest that postural sway is a measure of a combination of multiple factors, including sensory and visual, but can also be driven by environmental aspects or the posture of the adults. In our sample, a majority of participants needed some help to complete the assessment. This help was mostly required during 1 leg and tandem stance. This alone could be an indication of risk of falling. However, once given assistance to prevent falling during study from research assistants, postural sway scores were likely recorded as better than in actuality. This is perhaps why the visual-motion reaction scores, for which no physical assistance was needed from research assistants, became a better indicator of fall risk than the full assessment.

Our study has several limitations. Study participants were those who were willing to try the Senior Sway application; older adults uninterested or unwilling to use technology likely would not have agreed to participate in the study. However, the majority of participants reported being satisfied with the application, which may not have been the case if it had significant shortcomings from the user perspective. Furthermore, we had so much interest in testing the application that we had to schedule another day for recruitment and expand our initial expectation of enrollment of 40 to include 17 more. The participants in the study mostly included healthy and active adults, which therefore led to very few of the functional history predictors typically used in the geriatric assessment being correlated with Senior Sway. In addition, it should be noted that in comparing Senior Sway with functional tests, fall history, and IADL reporting, there are limitations in that these measures are not completely accurate predictors of fall risk. Also, there was unclear reporting on the need of assistance with the Senior Sway. We are unable to determine whether assistance was required for understanding the application or for performing the balance assessments. While only 11% reported needing a lot of assistance, a majority (56%) adults needed some assistance with completing the balance portions of the Senior Sway. This alone may in reality give clinicians the needed information as to whether or not a person may need referral to rehabilitation. However, we learned that the visual-motion reaction score did provide valuable added information, and we were ultimately able to outline a protocol for the use of Senior Sway that minimized assistance and clearly recorded the amount of assistance needed in static standing. The visual-motion reaction time could also lend knowledge to cognitive abilities of participants; however, we did not cover this aspect within the study. Cognitive ability has previously been shown to be associated with an increased risk for falls for older adults, so the visual-motion reaction score could provide another means of predicting falls.[33] Finally, the composite indicator needs further testing in larger sample sizes to determine its full usefulness and if the score should be dichotomous, categorical, or continuous. However, we considered it worthwhile as an indicator of some type of fall risk.

## CONCLUSION

In summary, Senior Sway is feasible to use within the community and many older adults in our sample liked using the application. Future prospective work is necessary to further evaluate the role of the application in identifying falls within clinics and the need for occupational and physical therapy. With further testing, Senior Sway has the potential be a useful tool in the primary care clinics and specialty clinics (eg, oncology, cardiology) to improve identification of adults who may need further evaluation and treatment to mitigate fall risk.

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