A smartphone fall risk application is valid and reliable in older adults during real-world testing

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K.L. Hsieh, J.T. Fanning, J.J. Sosnoff. A smartphone fall risk application is valid and reliable in older adults during real-world testing. Gerontechnology 2019;18(1):29-35; https://doi.org/10.4017/gt.2019.18.1.003.00 The purpose of this study was to determine the validity and reliability of a custom-built fall risk smartphone application (Steady^{TM}) compared to validated fall risk tests in older adults in a real-world setting. Fifteen participants completed Steady^{TM}, which includes entering demographics, rating perceived balance, and completing 5 balance tasks. Following completion, Steady^{TM} computes a single, overall fall risk score. Participants then completed standard, clinical tests assessing their mobility and overall fall risk. Ten participants repeated testing procedures within one week. Spearman's correlations and Interclass Coefficients (ICC) were performed between Steady^{TM} scores and clinical tests. There were moderate and significant correlations between Steady^{TM} scores and the mobility tasks (p's = 0.009 - <0.001). There was a good and significant ICC for Steady^{TM} scores between testing sessions (ICC = 0.90; p = 0.001). Steady^{TM} may offer a valid and reliable solution to provide self-administered fall risk screening for older adults in home settings.

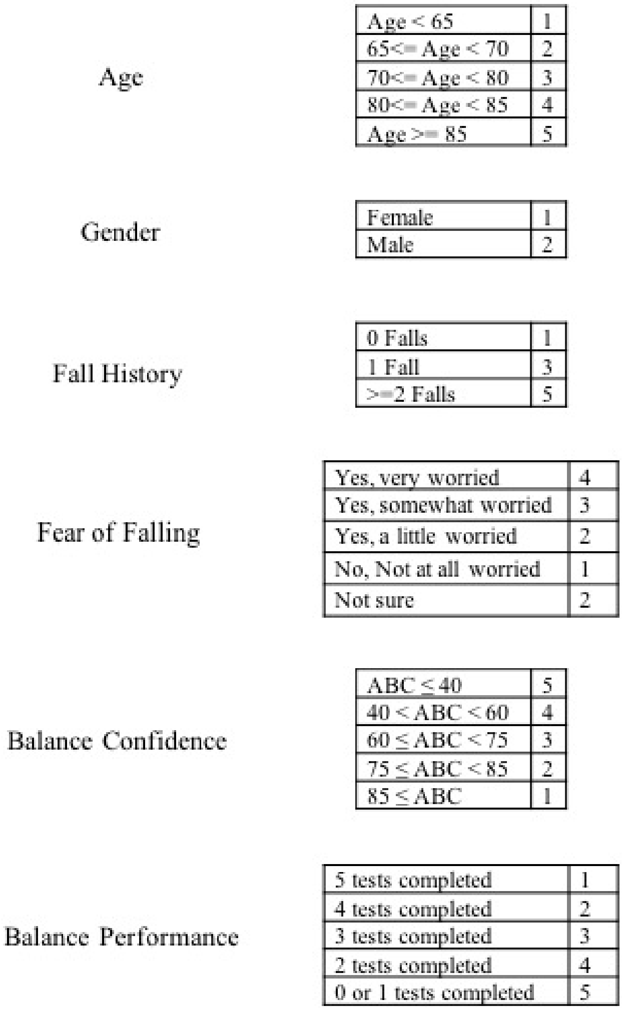
Keywords: fall risk, smartphone application, older adults

INTRODUCTION

One in four adults 65 years or older fall each year (DeGrauw, Annest, Stevens, Xu, & Coronado, 2016). Falls lead to physical and psychological injuries, such as physiological deconditioning, fear of falling, and even death (Lach, 2005; Terroso, Rosa, Marques, & Simoes, 2014). Despite the prevalence and detrimental consequences of falls, older adults seldom receive fall risk screening (Smith et al., 2015). This is due to various constraints, including expensive equipment, lack of clinicians' time, and lack of trained expertise (Smith et al., 2015). For instance, while clinical tests such as the Berg Balance Scale (Berg, 1989) or questionnaires such as the self-reported Activities Balance Confidence Scale (Powell & Myers, 1995) may be used for fall risk assessment, these tests require personnel to administer the test and interpret the findings. Additionally, these tests only assess aspects of balance whereas fall risk is multifactorial (Tchalla et al., 2014). Because of constraints in fall risk screening, many older adults remain unaware of their risk of falling and fail to take necessary steps to reduce their risk of falling.

Smartphone technology offers a solution to provide independent and self-administered fall risk screening. Unlike traditional balance and fall risk tools (i.e., force plates, motion capture cameras), smartphones are affordable, ubiquitous, and portable. Older adults are also the fastest growing group of smartphone users. As of 2017, 42% of adults 65 years and older own a smartphone, and 74% of adults aged 50-64 own smartphones (Anderson & Perrin, 2017). By embedding expert knowledge in a native smartphone or tablet application (app), older adults are able to understand their fall risk with minimal equipment and without the need of trained personnel. Most importantly, older adults are able to self-administer these assessments in their own homes, increasing the likelihood for continued fall risk monitoring.

Previous studies have tested smartphone technology and apps as a tool to measure fall risk. For instance, the uTUG is an app that measure performance on the Timed Up and Go (TUG) (Mellone et al., 2012). Another fall risk app is based on the Aachen Falls Prevention Scale and determines fall risk based on a set of questionnaires and a single balance task (Rasche et al., 2017). While these studies provide an important foundation for using smartphone apps to assess fall risk, they rely on a single measure or a single



Age

Age < 65	1
65<= Age < 70	2
70<= Age < 80	3
80<= Age < 85	4
Age >= 85	5

Gender

Female	1
Male	2

Fall History

0 Falls	1
1 Fall	3
>=2 Falls	5

Fear of Falling

Yes, very worried	4
Yes, somewhat worried	3
Yes, a little worried	2
No, Not at all worried	1
Not sure	2

Balance Confidence

ABC ≤ 40	5
40 < ABC < 60	4
60 ≤ ABC < 75	3
75 ≤ ABC < 85	2
85 ≤ ABC	1

Balance Performance

5 tests completed	1
4 tests completed	2
3 tests completed	3
2 tests completed	4
0 or 1 tests completed	5

Figure 1. Diagram of items imputed into the algorithm. Items are then weighted to create a single score. 1 = very low risk of falls, 2 = low risk of falls, 3 = moderate risk of falls, 4 = high risk of falls, 5 = very high risk of falls

questionnaire. A more recent study tested the usability of a self-guided fall risk app, and older adults reported high perceived usefulness and high ease of use (Hsieh et al., 2018). This app provides a more comprehensive and individualized measure of fall risk.

An app that is self-administered and provides an understandable fall risk score offers potential for older adults to become aware of their risk for falling and seek evidence-based fall prevention strategies. However, it is not clear if a self-administered smartphone fall risk app is valid and reliable compared to standard, clinical measures of fall risk. Therefore, the purpose of this study was to determine the validity and reliability of the smartphone app to measure fall risk in healthy, older adults in a real-world setting compared to clinical measures of fall risk. We hypothesized that a smartphone app will be valid compared to clinical fall risk measures and reliable across testing sessions.

METHODS

Participants

Fifteen community living older adults participated in validity testing. A subset of individuals (n=10) was selected for reliability testing based on availability. Participants were included if they were over 70 years old, able to use a touchscreen device, and able to stand with or without aide. All procedures were approved by the Institutional Review Board, and all participants completed written informed consent prior to participation.

Procedures

The smartphone application, Steady^{TM}, was developed specifically for older adults, which is of importance given the population's unique usability needs and preferences (Bernard, Liao, & Mills, 2001; Rogers, O'Brien, & Fisk, 2013). Briefly, the app consists of two components to compute a fall risk score (Hsieh et al., 2018). The first is a 13-item questionnaire of health history assessing age, gender, number of falls in the last year, and perceived balance confidence. The second component is a progressive postural stability test wherein the device guides participants through 5 balance tasks of progressive difficulty. These include four 30-second balance tasks (eyes open, eyes closed, tandem, single leg), plus a 30-second sit-to-stand test. On completion of each task, users report whether they attempted and were able to complete the task. These data, alongside data from the health history questionnaire, are entered into a weighted algorithm to produce a score ranging from 0-100 and classified into very low, low, moderate, high, and very high risk of falling. Lower scores represent a greater risk for falls. *Figure 1* depicts items that are imputed into the weighted algorithm. Fall risk is calculated based on the equation below, where wx represents the weight for each category. The weights for each category were determined from previous literature of factors

Table 1. Demographic information and clinical outcomes of all participants at baseline testing. Outcomes are represented as mean ± standard deviation unless otherwise indicated

Measure	**Mean ± Standard Deviation**
Age (years)	83.87 ± 5.03
Gender	9 females & 6 males
Highest Level of Education	1 High School 2 Some College 2 Bachelor's Degree 6 Master's Degree 4 PhD or equivalent
Smartphone Ownership	10 owners (4 Android & 6 Apple)
Steady Score	50.05 ± 17.17
Timed Up and Go (seconds)	9.90 ± 2.97
Five Times Sit-to-Stand (seconds)	10.93 ± 2.88
Berg Balance Scale	50.07 ± 6.38
Physiological Profile Assessment	1.84 ± 1.05
Activities Balance Confidence	79.35 ± 14.34

that predict fall risk in older adults (Lach, 2005; Myers, Fletcher, Myers, & Sherk, 1998; Tchalla et al., 2014). This score is then converted to the Steady^{TM} score which ranges from 0-100, and x represents a constant.

Fall Risk = w1*(Age Category) + w2*(Gender Category) + w3*(Fall History Category) + w4 *(Fear of Falling Category) + w5*(Balance Confidence Category) + w6*(Balance Category)
Steady^{TM} Score = 100 – 100*[(Fall Risk -1)/x]

All participants completed testing in an apartment at an independent living retirement center. Participants first completed fall risk screening independently using the app on a smartphone device (Samsung Galaxy S6). Researchers were present to answer questions, but participants were required to navigate the app on their own.

Following completion of the app, participants performed clinical measures of balance and fall risk assessment including the Physiological Profile Assessment (PPA), Berg Balance Scale, Timed Up and Go (TUG), and 5 times sit-to-stand. These assessments were selected since they have been found to be valid and reliable indicators of fall risk in older adults (Buatois et al., 2008; Lord, Menz, & Tiedemann, 2003; Muir, Berg, Chesworth, & Speechley, 2008; Shumway-Cook, Brauer, & Woollacott, 2000). The PPA consists of 5 tasks and produces an overall fall risk score. Tasks include: (1) contrast vision test, (2) leg strength, (3) simple reaction time, (4) proprioception, and (5) eyes open balance on a foam surface (Lord et al., 2003). Overall physiological fall risk from the 5 tests was derived and converted into z-scores. The Berg Balance Scale is a 14-item list of balance tasks such as turning in a circle and transferring between two chairs. Each task results in a score between 0 and 4, and all scores are summed to produce a final score between 0 and 56, with higher scores represent better balance (Muir et al., 2008). The TUG consists of standing from a chair, walking ten feet, turning back around to sit in the chair as quickly as possible. The 5 times sit-to-stand consists of standing and sitting from a chair five times as quickly as possible. Two trials of the TUG and sit-to-stand were completed and averaged. Shorter time to completion is indicative of better function on each task. Participants were provided rest between tests if needed. They also completed the Activities Balance Confidence (ABC) Scale, a 16-item scale of perceived confidence during activities of daily living ranging from walking around the home to walking on icy sidewalks (Myers et al., 1998). The average of the 16 items of the ABC was calculated. The ABC scale has shown to be related to falls and recurrent falls in community-dwelling older adults (Myers et al., 1998).

A subset of participants (n=10) were asked to repeat all testing procedures within a week (average 5 +/- 2 days) to determine test-retest reliability. These participants were selected solely based on their availability to return within a week to repeat testing procedures.

Statistical analysis

Spearman's rank order correlations were performed to determine the relationship between the SteadyTM score and the PPA, TUG, 5 times sit-to-stand, Berg Balance Scale, and ABC. Spearman's correlations of 0.1-0.3 represent low correlations, 0.3-0.5 represent moderate correlations, and above 0.5 represent excellent correlations (Cohen, West, & Aiken, 2014). To determine test-retest reliability, interclass correlation coefficients (ICC) were calculated (Weir, 2005). ICC less than 0.5 indicate poor reliability, between 0.5 and 0.75 indicate moderate reliability, between 0.75 and 0.9 indicate good reliability and over 0.9 indicate excellent reliability (Koo & Li, 2016).

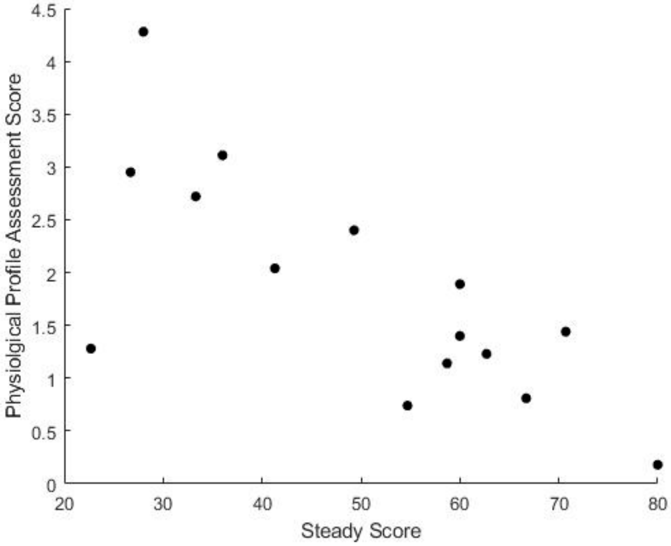


Figure 2. Scatter plot of Steady^{TM} Scores and fall risk from the Physiological Profile Assessment

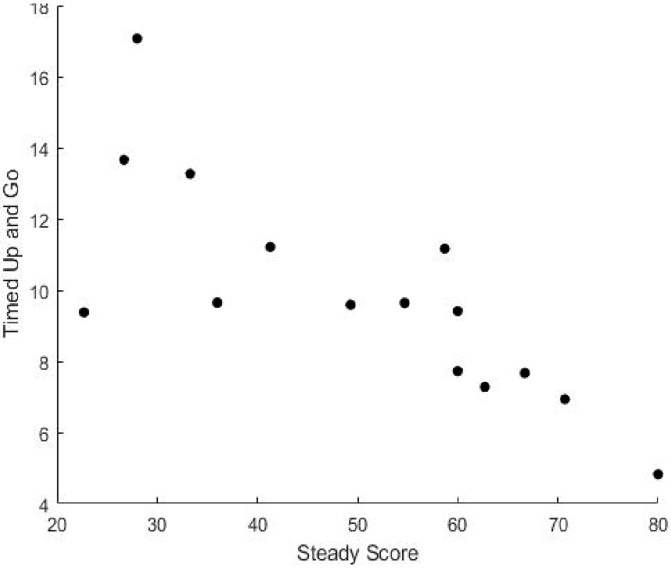


Figure 3. Scatter plot of Steady^{TM} Scores and the Timed Up and Go

Results

Participant demographics and clinical outcomes are reported in *Table 1*. SteadyTM scores ranged from 36 to 80, TUG ranged from 7.68 to 17.07 seconds, 5 times sit-to-stand ranged from 5.85 to 15.95 seconds, PPA ranged from 0.81 to 4.28, Berg Balance Scale ranged from 30 to 56, and the ABC ranged from 63.75 to 97.81.

Spearman's correlations found moderate to excellent correlations between the Steady^{TM} score and the PPA (Rho = -0.65; p = 0.009; *Figure 2*), TUG (Rho = -0.80; p < 0.001; *Figure 3*), Berg Balance Scale (Rho = 0.88; p < 0.001; *Figure 4*), and the ABC (Rho = 0.70; p = 0.004; *Figure 5*). There was not a significant correlation between the Steady^{TM} score and sit-to-stand (Rho = -0.42; p = 0.137).

There was a good and significant ICC of Steady^{TM} scores between the first and second testing sessions (ICC = 0.90; p = 0.001). There was also good and significant ICC between the first and second testing sessions for the TUG (ICC = 0.91 p = 0.001), PPA (ICC = 0.76; p = 0.031), Berg Balance (ICC = 0.89; p = 0.003); and 5 times sit-to-stand (ICC = 0.88; p = 0.008).

Discussion

The purpose of this study was to determine whether a self-administered smartphone fall risk application was valid compared to a battery of clinical and self-reported measures of fall risk and reliable across sessions. The results support our hypothesis that Steady^{TM} was comparable to clinical and self-report fall risk measures. Fall risk reported from Steady^{TM} was also found to be reliable between the first and second testing session. These results suggest that a fall screening app utilized by older adults may provide valid and reliable fall risk scores in home settings.

To the authors' knowledge, this is the first study to determine the validity of a self-administered, smartphone-based fall risk app compared to clinical measures of balance and fall risk. A pervious study tested a custom app designed to measure fall risk and collected data from 79 German users ranging from 50 to 70 years old who downloaded the app (Rasche et al., 2017). The self-reported number of falls in the last year significantly corresponded to fall risk recorded by the app (Rasche et al., 2017). However, the investigation did not compare fall risk derived from the app to standard clinical measures of fall risk. In contrast, the current investigation provides a further step in determining the relationship between fall risk assessed via app compared to clinical balance and fall risk tests. Another study developed an app called the uTUG, which measures performance during the TUG (Mellone et al., 2012). However, this app was not validated and did not test the app for older adults. FallCheck is another app that is a

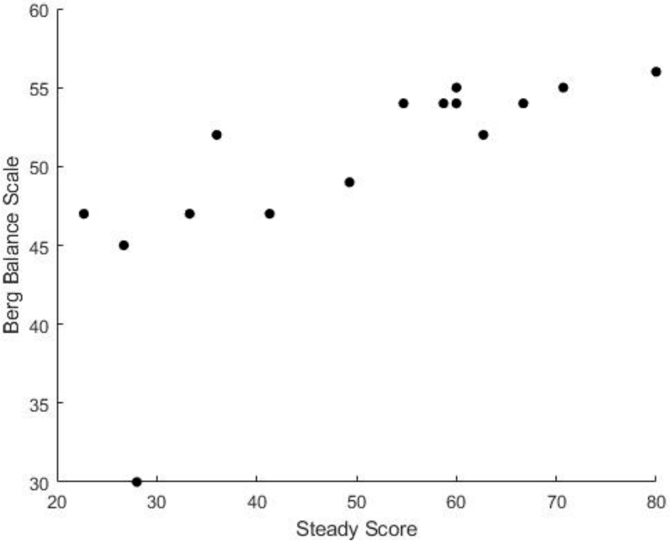


Figure 4. Scatter plot of Steady^{TM} Scores and the Berg Balance Scale

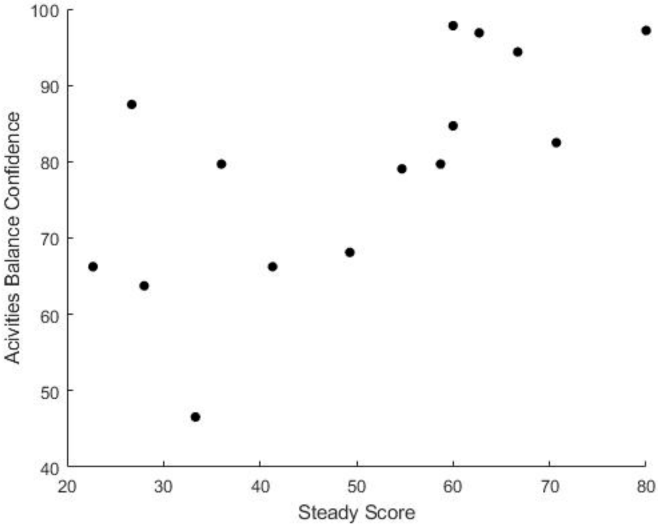


Figure 5. Scatter plot of Steady^{TM} Scores and the Activities Balance Scale

checklist of environmental factors in the home that may be fall hazards (Hayes, 2015). In its current iteration, Steady^{TM} does not incorporate environmental fall risk factors, but future iterations should include a checklist like FallCheck to provide a more comprehensive fall risk score.

Fall risk is multifactorial, and comprehensive fall risk assessment that has the potential for largescale accessibility has been recommended for older adults ("Summary of the Updated American Geriatrics Society/British Geriatrics Society clinical practice guideline for prevention of falls in older persons," 2011). The smartphone application tested here follows these recommendations and provides a comprehensive fall risk assessment. Steady^{TM} incorporates key predictors of fall risk (i.e., age, previous falls, fear of falling, perceived balance, balance performance) to compute a single, easy-to-understand score. Moreover, unlike other health apps that require GPS or accelerometry, Steady^{TM} requires minimal hardware requirements of a smartphone providing potential to reach a large population of older adults and opportunities for delivery via other smart devices. For the first time, older adults can undergo a self-assessment of fall risk and receive a single, easy-to-understand score. This is a critical step for older adults prior to seeking fall prevention interventions.

Steady^{TM} was correlated with a battery of diverse fall risk assessments. For instance, the PPA represents a composite measure of fall risk (Lord et al., 2003), the TUG represents walking and turning (Podsiadlo & Richardson, 1991), the Berg Balance Scale represents overall balance (Berg, 1989; Downs, Marquez, & Chiarelli, 2014), and the ABC represents perceived balance (Powell & Myers, 1995). Our current observations indicate that Steady^{TM} is valid compared to these multiple measures of balance and fall risk. Providing self-guided, validated, and reliable fall risk assessment on a smartphone offers potential to provide accessible and comprehensive falls screening for older adults.

This study is also the first to determine the validity and reliability of a fall risk app in a real-world setting. Steady^{TM} was not only reliable across testing sessions, but its ICCs were comparable to ICCs of the clinical tests. Participants also tested this app in an apartment that is similar to a typical apartment at a retirement center. Past studies of smartphone-based falls risk assessment were performed in controlled, lab-based settings (Roeing, Hsieh, & Sosnoff, 2017). This current study provides evidence that a fall risk app may be used outside of a lab-setting. Additionally, because smartphones are commercially available, cost-efficient, and portable, smartphones offer high potential to bring falls screening to home settings. Given the high prevalence of falls and their detrimental consequences, along with the constraints of clinical screening, there is a need for an affordable, available, and self-administered fall risk tool. This study suggests that

Steady™ is valid and reliable when tested in a real-world setting and may offer potential to bring fall risk screening in home settings.

One limitation of the study is a small and highly educated sample size. Almost all participants also own smartphones and have experience using smartphones. Future testing should include a larger and more diverse sample for validity and reliability testing. Furthermore, future directions should determine whether incorporating data from the smartphone's onboard accelerometer is useful for providing more detailed feedback to the participant (e.g., pace of chair rises). Whether Steady™ scores are predictive of future falls should also be determined.

CONCLUSION

This study determined the validity and reliability of a fall risk application in older adults in a real-world setting. Fall risk scores from Steady™ were comparable to the PPA, TUG, Berg Balance Scale, and ABC. SteadyTM scores also demonstrated strong and significant test-retest reliability. This study was performed in an independent retirement center, offering promise in providing smartphone-based fall risk assessment in home settings. Gerontechnologists can utilize commercially available technology to provide older adults with knowledge of their risk for falling. Providing individual fall risk is an important step for gerontechnologists to develop intervention strategies for older adults. Because falls are both common and devastating to older adults, and fall risk screening is vital to fall prevention. Leveraging smartphone technology to move fall screening into the home stands to have an important public health impact.

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