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Concordance of Motion Sensor and Clinician-Rated Fall Risk Scores in Older Adults

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As the older adult population in the United States continues to grow, developing reliable, valid, and practical methods for identifying fall risk is a high priority. Falls are prevalent in older adults and contribute significantly to morbidity and mortality rates and rising health costs. Identifying at-risk older adults and intervening in a timely manner can reduce falls. Conventional fall risk assessment tools require a health professional trained in the use of each tool for administration and interpretation. Motion sensor technology, which uses three-dimensional cameras to measure patient movements, is promising for assessing older adults' fall risk because it could eliminate or reduce the need for provider oversight. The purpose of this study was to assess the concordance of fall risk scores as measured by a motion sensor device, the OmniVR Virtual Rehabilitation System, with clinician-rated fall risk scores in older adult outpatients undergoing physical rehabilitation. Three standardized fall risk assessments were administered by the OmniVR and by a clinician. Validity of the OmniVR was assessed by measuring the concordance between the two assessment methods. Stability of the OmniVR fall risk ratings was assessed by measuring test-retest reliability. The OmniVR scores showed high concordance with the clinician-rated scores and high stability over time, demonstrating comparability with provider measurements.

KEY WORDS: Fall prevention, Fall risk, Motion sensors, Older adults

Falls in older adults (60 years and older) are a major health issue. More than 700 000 persons per year are hospitalized because of a fall-related injury, accounting for healthcare costs of more than $34 billion annually.[1] Mortality rates related to falls are substantial. Falls among older adults account for 67.9 deaths per 100 000 among men and 49.1 deaths per 100 000 among women.[2]

Identifying at-risk older adults through conventional fall risk assessments conducted by skilled providers and intervening in a timely manner can substantially reduce falls in the clinical or home setting.[3–5] However, many older adults have no access to conventional fall risk assessments because of lack of access to healthcare providers, difficulty navigating the healthcare system, and care coordination delays.[6] Recent developments in a variety of motion sensor devices have allowed for integration of fall risk assessments that may hold the potential to reduce or even eliminate the need for provider administration. Limited data suggest that some commonly used motion sensors yield fall risk assessment scores that are comparable with conventional fall risk assessments.[7–11] In addition, motion sensor assessments are inherently protected from rater subjectivity because they are delivered by machine, and patients can use motion sensors to self-administer fall risk assessment tests at home or in community environments.

One motion sensor device, the OmniVR (Accelerated Care Plus, Reno, NV), was developed to assess balance and fall risk in older adults in a rehabilitation setting; however, reliability and validity data have not been publicly disseminated. This motion sensor device was selected because of its specific target population and its ability to perform standardized fall risk assessments. The purpose of this study was to assess the concordance of OmniVR fall risk assessment ratings with clinician ratings in older adults in a rehabilitation setting. A secondary purpose was to explore the stability of OmniVR fall risk assessment ratings.

METHODS

Design

This study used a nonexperimental, repeated-measures design. Three gait and flexibility tests (described in the "Measures" section) were administered twice to each participant: once by the OmniVR motion sensor device and once by the principal investigator. The order of administration was randomized by computer to control for order effects.

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Setting and Sample

A sample of older adults receiving rehabilitative care at a retirement community in the Pacific Northwest was recruited to the study via advertisement posters and referral by staff providers (physical therapists and occupational therapists).

Eligible participants met the following inclusion criteria: (1) 60 years of age or older; (2) able to attend to and understand verbal cues and follow simple instructions as evidenced by a cognitive level of at least 4.4, as measured by the Allen Cognitive Levels Screening[12]; (3) able to perform the gait assessment tests; and (4) able to speak and read English.

Healthy adult volunteers without rehabilitation needs were also recruited to serve as controls to provide a wider range of scores to assess motion sensor validity and reliability. Eligible participants met the following inclusion criteria: (1) aged 18 or older, (2) able to perform the gait assessment tests, (3) able to speak and read English, and (4) have no known gait or balance limitations (as identified by the participant).

Measures

Participants were assessed using three validated gait and flexibility tests that are widely used in rehabilitation settings to assess fall risk. The components of each test are programmed into the OmniVR, allowing the motion sensor device to produce a score.

Functional Reach Test

The Functional Reach (FR)[13] test was used to assess forward balance and has been shown to predict the risk of falls.[14] The FR test has demonstrated excellent intrarater and interrater reliability ($r = 0.93–0.99$),[15,16] as well as predictive validity in relation to recurrent falls (odds ratio, 8.07 [2.8–23.71]),[17] convergent validity with other tests ($r = 50.48$),[15] and criterion-related validity.[18]

For the FR test, participants were asked to stand with one shoulder close to a wall and the ipsilateral hand extended at a 90° angle along the wall with a closed fist. The clinician (healthcare provider) recorded the starting position at the third metacarpal head (middle finger knuckle when making a fist) using a wall-mounted yardstick. Participants were then asked to "reach as far as you can forward without taking a step." After reaching forward, the position of the third metacarpal was again recorded, and scores were obtained by calculating the difference between the two scores (the reach distance in inches). The final score was an average of two attempts.[13]

10-Foot Timed Up and Go Test

The 10-foot Timed Up and Go (TUG) test was used to assess agility and dynamic balance. The validity of the TUG test has been supported by the findings that TUG times are significantly slower in fallers when compared with nonfallers[19] and that longer TUG times significantly predicted the occurrence of falling in a 1-year follow-up period.[15] Effect sizes for the TUG in responsiveness to falls and activities of daily living (ADL) decline and improvement were 0.12, 0.42, and 0.05, respectively.[15] The TUG test has been found to have high retest reliability and interrater reliability ($r = 0.93–0.99$).[15,20]

For the TUG test, participants were timed as they rose from a seated position in a standard armchair, walked 10 feet at a normal pace, turned, and returned to a seated position. If participants were able to repeat the TUG test, the average of the two trials was calculated. If participants were only able to perform the TUG test once, that score was used.

Sit-to-Stand Test

The Sit-to-Stand (STS) test was used to measure lower body strength. The STS test has been found to have excellent test-retest intraclass correlations in older adults (0.84 for men, 0.92 for women).[21]

For the STS test, participants were seated in a sturdy armless chair and were asked to stand up and sit down without using their hands as many times as possible in 30 seconds.

Motion Sensor Device

The OmniVR is a motion sensor tracking device that performs gait and flexibility assessments using a three-dimensional (3D) camera. The 3D camera and computer software track patients' movements as they interact with a virtual world. The OmniVR was designed for use with geriatric rehabilitation patients with complex conditions and has the capacity to perform assessments, as well as training exercises.[22] This device is an emerging technology, and so far, reliability and validity data for the OmniVR measures have not been independently reported.

Procedures

Institutional review board approval was obtained from the relevant sites. The principal investigator (PI) described the study to the participants, and informed consent was obtained before any testing. The OmniVR device was operated by the clinician (PI), who selected the tests to be administered by the device. Each measure was performed twice at baseline: once by the clinician and once by the OmniVR. Order of testing (clinician first vs OmniVR first) was randomized by computer database according to participant identification number. A standard rest period of 10 minutes took place between the two sets of measures (more time was given when requested by the participant).

In a randomized-by-computer subset of the sample, the OmniVR and provider assessments were repeated approximately 1 week after the initial assessment. Participants who were unable to return for the retest period were automatically classified in the one-time testing group. The subset was tested again in the same order after a set period (roughly 1 week, scheduled individually by the participant) after the baseline measurements.

DATA ANALYSIS

Data management and statistical analysis were conducted using IBM SPSS Statistics version 22 (IBM, Armonk, NY) and Microsoft Excel (Microsoft, Redmond, WA). A two-tailed .05 significance level was used for all statistical tests. The concordance of the OmniVR and clinician scores were tested using intraclass correlations. The stability of the OmniVR and clinician scores were tested using Pearson correlation coefficients.

RESULTS

The flow chart for the study is shown in Figure 1.

Sample Demographics

Fifteen participants were enrolled in the study (n = 12 older adults, n = 3 healthy young controls) (Table 1). Most participants were white and female, and the groups' age ranges were 60 to 89 years (mean, 81.9 ± 8.9 years) for the older adult group and 19 to 47 years (mean, 30.7 ± 14.6 years) for the control group.

Concordance of the OmniVR and Clinical Ratings

The intraclass correlations for each test were 0.85 or greater and were statistically significant. Correlations for FR and STS were significant at less than 0.05, while the TUG correlation was significant at less than 0.01 (Table 2).

Differential Variability Between Rehabilitation Subjects and Healthy Subjects

Our Bland-Altman graphs (see Figures 2 through 4) showed that the three healthy subjects (with no gait problems) had less variability in their scores irrespective of order of administration.

Table 1. Description of Participants

Category	n (%)
Sex	
Male	5 (33.3)
Female	10 (66.7)
Age range, y	19–89
Older adults, mean (SD)	81.92 (8.88)
Controls, mean (SD)	30.67 (14.57)
Rehabilitation adults	12 (80)
Controls	3 (20)
Repeat measures	7 (46.7)
One-time measures	8 (53.3)

Stability Over Time

For the OmniVR ratings, statistically significant correlations were found for both the TUG ($P < .01$) and the STS ($P < .01$), but not for the FR. For the clinician ratings, only the correlation for the STS was statistically significant ($P < .01$) (see Table 3). The powers were 60%, 62%, and 72% for the three correlations that were marginal (TUG clinician-rated stability, FR OMNI-stability, and FR clinician-rated stability, respectively) (see Table 3).

We observed differential variability in participants' scores as measured by the OmniVR and clinicians. The Bland-Altman graphs showed that the three healthy subjects (with no gait problems) had less variability in their scores irrespective of order of administration. In contrast, some of the rehabilitation subjects performed worse on the second test administered, regardless of whether it was administered by the OmniVR or the clinician. Four rehabilitation participants were unable to complete the first testing condition because of profound muscle weakness, and their data were omitted from the study.

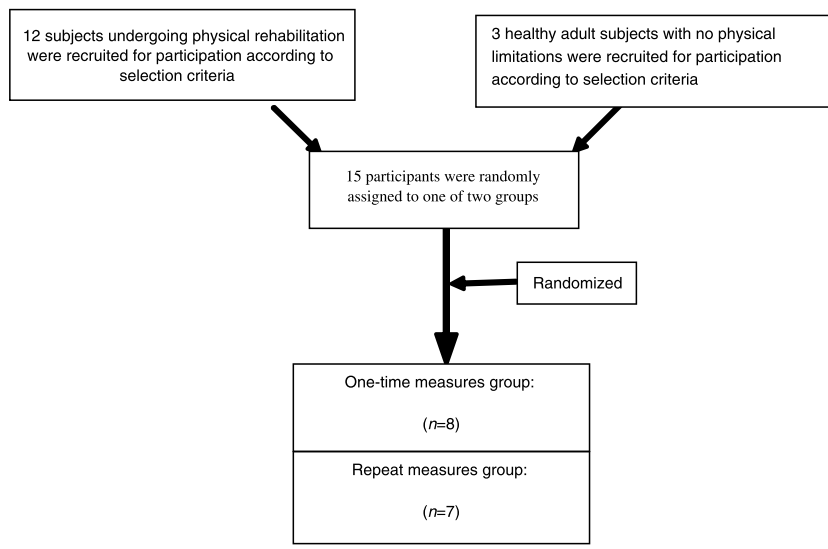


FIGURE 1. Flow chart.

Table 2. Concordance of OmniVR and Clinician Ratings

Measure	Sample Size	ICC
10-Foot Timed Up and Go	10	0.91[a]
Functional Reach	13	0.85[b]
Sit to Stand	10	0.99[b]

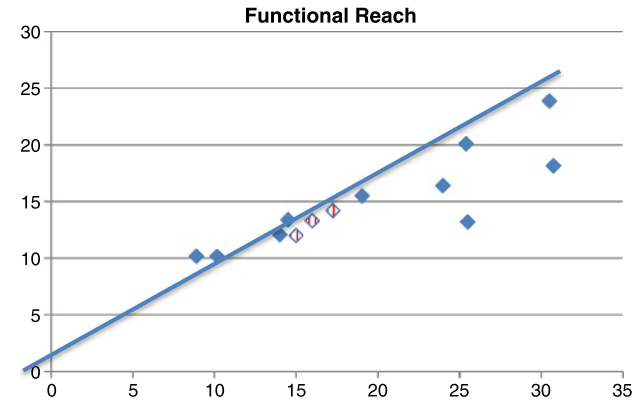
[a]$P < .01$.
[b]$P < .05$.

DISCUSSION

We found a high level of concordance between the OmniVR and clinician-rated fall risk assessment scores. In addition, we found higher stability in OmniVR ratings than clinician ratings. Not surprisingly, rehabilitation subjects tended to show lower scores on their second assessment, suggesting the effects of fatigue.

Our findings suggest that the OmniVR may be a viable alternative for assessing older adults' fall risk and add to a growing body of literature demonstrating the reliability and validity of motion sensor–based fall risk assessments. Wearable motion sensors have demonstrated the ability to differentiate older adults classified as high and low fall risk by identifying deterioration of walking cadence.[11] Predictive validity has been shown by the finding that baseline motion sensor–based fall risk assessments of geriatric inpatients showed comparable sensitivity and specificity to clinician ratings when predicting falls during the ensuing 12 months.[10] Test-retest reliability and sensitivity of the Microsoft Kinect motion sensor were found to be acceptable (intraclass correlation coefficient [ICC], 0.9) when the device evaluated upper body function in both patients with stroke and healthy subjects.[23] The Microsoft Kinect has also demonstrated moderate to good intrarater reliability in evaluating static foot posture ($\rho = 0.62–0.78$) compared with poor to moderate ($\rho = 0.17–0.63$) intrarater reliability when foot posture was assessed visually by providers.[23] In an accelerometer study examining STS test peak power, the accelerometer motion sensor demonstrated excellent test-retest reliability in younger adults (ICC $\geq$ 0.90) and older adults (ICC, 0.73).[24]

Expanded access to motion sensors and improved ease of use could transform fall risk prevention strategies by empowering patients to self-monitor. Motion sensors can facilitate older adults' early detection of gait and flexibility issues so that appropriate preventive measures can be implemented.

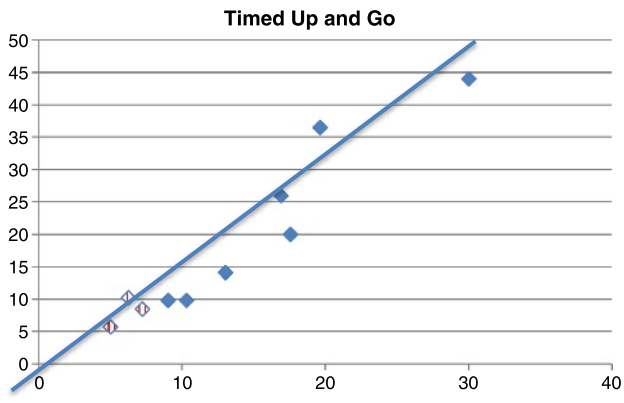


Older adult rehabilitation subjects depicted with solid point markers; healthy adult subjects depicted with stripe patterned point markers.

FIGURE 3. Concordance of OmniVR and clinician measures, FR.

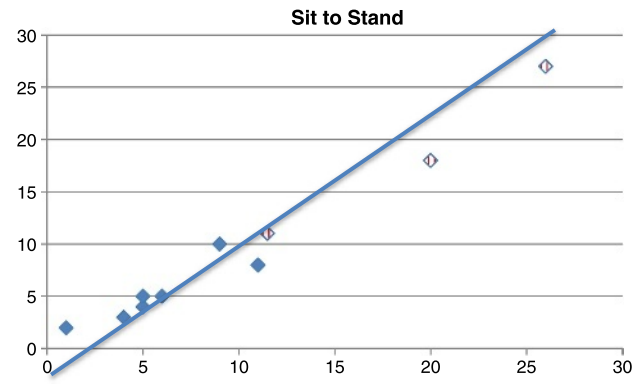
STUDY LIMITATIONS

The homogeneity of the study sample may limit generalizability to other clinical populations. Similarly, findings from the OmniVR may not be generalizable to other motion sensors because it was designed specifically for use with an older adult rehabilitation population. We limited our sample to older adult rehabilitation outpatients; thus, the findings may



Older adult rehabilitation subjects depicted with solid point markers; healthy adult subjects depicted with stripe patterned point markers.

FIGURE 2. Concordance of OmniVR and clinician measures, TUG.



Older adult rehabilitation subjects depicted with solid point markers; healthy adult subjects depicted with stripe patterned point markers.

FIGURE 4. Concordance of OmniVR and clinician measures, STS.

Table 3. Test Stability

Measure	OMNI-Rated Sample	OMNI Stability	Clinician-Rated Sample	Clinician-Rated Stability
10-Foot Timed Up and Go	6	0.98[a]	7	0.65
Functional Reach	6	0.68	7	0.73
Sit to Stand	7	0.99[a]	7	0.98[a]

[a] $P < .01$.

not generalize to inpatients who may have comparatively lower functional status. This study examined a small sample at a single institution. The follow-up testing period approximated 1 week but was variable because rehabilitation participants were outpatients who were retested at their next scheduled visit or at their convenience. A larger sample with a standardized retest period is needed to confirm our findings that the fall risk assessments performed by the OmniVR were more stable than the clinician ratings.

CONCLUSIONS

In conclusion, we found that fall risk assessments performed by the OmniVR were comparable with clinician-rated assessments. In addition, the stability of OmniVR ratings was superior to clinician ratings. These findings provide preliminary evidence to support the use of the OmniVR to assess fall risk. Additional studies with larger samples, in different settings, and with other clinical populations are warranted to support the external validity of these findings. A logical next step would include tool validation of this or similar motion sensor devices with a population of community-dwelling older adults.

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