Original Study

Construct Validity of a Modified Bathroom Scale That Can Measure Balance in Elderly People

Joan Vermeulen MSc, Jacques C.L. Neyens PhD, Marieke D. Spreeuwenberg PhD, Erik van Rossum PhD, David J. Hewson Prof, Jacques Duchêne Prof, Luc P. de Witte MD

School for Public Health and Primary Care (CAPHRI), Maastricht University, Department of Health Services Research, Maastricht, The Netherlands
Research Center Technology and Care, Zuyd University of Applied Sciences, Heerlen, The Netherlands
Institut Charles Delaunay (ICD), UMR CNRS 6279, Université de Technologie de Troyes, Troyes, France

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ABSTRACT

Objectives: To investigate the construct validity of a bathroom scale measuring balance in elderly people.

Design: Cross-sectional study.

Setting: Participants were recruited via nursing homes and an organization that provides exercise classes for community-dwelling elderly people.

Participants: Nursing home patients were compared with active community-dwelling elderly people. Eligibility criteria for both groups were: aged 65 years or older and being able to step onto a bathroom scale independently.

Measurements: The balance measurement of the bathroom scale was compared with the following three clinical balance measurements: Performance Oriented Mobility Assessment (POMA), Timed Up and Go (TUG), and Four Test Balance Scale (FTBS). An independent samples t-test was performed to determine whether nursing home patients scored lower on these four balance tests compared with community-dwelling elderly people. Correlations were calculated between the bathroom scale balance scores and those of the clinical balance tests for nursing home patients and community-dwelling elderly people separately.

Results: Forty-seven nursing home patients with a mean age of 81 years (SD 6.40) and 54 community-dwelling elderly patients with a mean age of 76 years (SD 5.06) participated in the study. The results showed that nursing home patients had significantly lower scores on all four balance tests compared with community-dwelling elderly people. Correlations were significant in active community-dwelling elderly people, .49, .60, and .63, respectively. These correlations were not significant in active community-dwelling elderly people, .04, .42, and .33, respectively. Linear regression analyses showed that the correlations for the bathroom scale and POMA, bathroom scale and TUG, and bathroom scale and FTBS did not differ statistically between nursing home patients and community-dwelling elderly people.

Conclusion: These results suggest that the modified bathroom scale is useful for measuring balance in elderly people. However, the added value of this assessment method for clinical practice remains to be demonstrated.

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A literature review by Langley et al identified 17 different clinical balance tests that are used to measure functional balance in elderly people. Two tests with good psychometric properties that are often used in clinical practice are the Performance Oriented Mobility Assessment (POMA) and the Timed Up and Go test (TUG). To get a good impression of the development of balance over time, performance based tests should be administered on a regular basis. This is very difficult, if not impossible, to accomplish in daily practice.

A modified bathroom scale that enables elderly people to measure their own balance by stepping onto the scale could be a solution for this problem. Such a scale was developed by the University of Technology of Troyes in France. An algorithm is used to extract information regarding balance from the sensors that are embedded in the bathroom scale. The bathroom scale is equipped with Bluetooth, which enables the transfer of balance and weight data to a database that can be accessed by healthcare professionals. The acceptability and usability of the device were evaluated in a longitudinal study. Elderly people accepted the modified bathroom scale and were able to use it because it does not differ from a normal bathroom scale. A recent validation study compared balance measurements of the bathroom scale with those of a force plate. The results indicated that the validity of the bathroom scale was good, with no differences found between standard balance parameters measured with a force plate and the bathroom scale. A clear advantage of the bathroom scale over the force plate is that it is much less expensive.

As mentioned above, clinicians usually use physical performance tests to measure balance in elderly people. Force plates and other sophisticated laboratory tests are rarely used in clinical practice because the equipment is quite costly. Therefore, the aim of this study was to determine the construct validity of the bathroom scale by comparing its balance measurements to those of clinical tests that are used in daily practice. This study focused on the following two research questions: (1) do the measurements of the bathroom scale confirm that nursing home patients have poorer balance compared with community-dwelling elderly people, and (2) how do the balance scores of the bathroom scale relate to those of clinical balance tests that are used in daily practice?

**Design, Setting, and Participants**

This study had a cross-sectional design. To determine known-groups validity, elderly people with poor and good balance needed to be represented in the study sample. Therefore, participants were recruited via nursing homes and an organization that provides professionals. The acceptability and usability of the device were evaluated in a longitudinal study. Elderly people accepted the modified bathroom scale and were able to use it because it does not differ from a normal bathroom scale. A recent validation study compared balance measurements of the bathroom scale with those of a force plate. The results indicated that the validity of the bathroom scale was good, with no differences found between standard balance parameters measured with a force plate and the bathroom scale. A clear advantage of the bathroom scale over the force plate is that it is much less expensive.

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**Procedures**

Once written informed consent was provided by 47 nursing home patients and 54 community-dwelling elderly people, the researcher visited the nursing homes and the exercise classes to conduct all balance measurements. To ensure that the balance tests would not be too strenuous, only a limited number of clinical tests could be conducted per participant. All 101 participants performed one balance measurement with the bathroom scale. POMA was conducted in 69 participants. TUG and Four Test Balance Scale (FTBS) were administered instead of the POMA in the remaining 32 participants.

**Measurements**

In total, four different balance measurements were conducted. The bathroom scale measurements were conducted under supervision of the researcher. The three clinical balance tests were conducted by a physiotherapist specialized in geriatrics.

The bathroom scale balance measurement was conducted in all participants. The scale is equipped with an infrared sensor at the front, which activates the bathroom scale. All participants were instructed to stand in front of the scale and to step onto it when the number “0.0” appeared on the display. They were instructed to step down backwards once their weight appeared on the screen. The modified bathroom scale uses the signals from four force sensors located in the corners of the scale to collect information regarding various parameters. An overall balance indicator is calculated using the information from four parameters: step on delay, rise rate, surface under the stabilogram, and the average velocity of the trajectory. Each parameter is scored on a scale from 0 to 4, which results in an overall balance score between 0 and 16. A higher score indicates better balance. More detailed information regarding the parameters and the calculation of the overall balance score is described in a previous article by Duchêne and Hewson.

POMA consists of a balance and gait subscale. Among the balance tasks were: balance while sitting, rising, attempting to rise, immediate standing, standing with alterations in base of support, sternal nudge, standing with eyes closed, turning 360°, and sitting down again. Among the gait tasks were: initiation, step length, step height, step symmetry, step continuity, path, trunk stability, and step width. Each task was scored by a trained physiotherapist with 0, 1, or 2. Scores on the POMA ranged from 0 to 28. A higher score indicates better performance on the tasks.

TUG assessed how long it took participants to rise from a chair, walk 3 meters, turn around, walk back, and sit back down in the chair. Participants wore regular footwear and were allowed to use a walking aid if they did so for their routine daily activities. The time it took to perform the TUG was scored in seconds. A lower score indicates better performance.

FTBS was used to measure how long participants could hold a parallel stand, a semi-tandem stand, a tandem stand, and stand on one leg. Participants were encouraged to hold each standing test for 10 seconds without losing balance, starting with standing in parallel and increasing the difficulty after each 10 seconds if possible. A total score was calculated for the FTBS by adding the seconds a person was able to remain standing without losing balance on each of the four standing tests. This resulted in a sum score between 0 and 40 where a higher score indicates better balance.

**Statistical Methods**

Descriptive statistics were used to provide information on the characteristics of the participants and the balance measurements. Categorical variables were expressed with percentages and
Results

Participants

The participation rate in the group of nursing home patients was 87%. In the first nursing home, 29 of the 34 invited patients participated (85%). In the second nursing home, 18 of the 20 invited patients participated (90%). The participation rate in the group of community-dwelling elderly people was 84%, 54 of the 64 invited elderly people participated. In the first exercise class, 13 of the 23 invited elderly people participated (56%). In the other three exercise classes, all people who were invited participated in the study. So in total, 101 participants were included in the analyses. Not all clinical balance tests were administered to all participants; Figure 1 shows which clinical balance tests were administered in which participants.

The test with the modified bathroom scale was conducted in all participants. The POMA was administered to 32 nursing home patients (9 men and 23 women) and 37 community-dwelling elderly people (5 men and 32 women). The TUG and FTBS were administered to 15 nursing home patients (7 men and 8 women) and 17 community-dwelling elderly people (17 women). Table 1 presents the characteristics of the participants for nursing home patients and active community-dwelling elderly people. More men were included in the group of nursing home patients compared with the group of community-dwelling elderly people. Besides that, nursing home patients were older. Nursing home patients scored lower on all balance tests compared with community-dwelling elderly people. T-test statistics were $T(99) = -6.76$, $P < .01$, $T(67) = -7.57$, $P < .01$, $T(30) = 4.27$, $P < .01$, and $T(30) = -3.24$, $P < .01$ for the bathroom scale, POMA, TUG, and FTBS, respectively.

Relation Between Balance Measurements

Table 2 presents the correlations between the balance measurements of the four different tests for the nursing home patients and community-dwelling elderly people separately. In nursing home patients, all correlations were of moderate strength and were significant whereas in community-dwelling elderly people the correlations were weaker and not significant. The linear regression analyses showed that the correlations between the bathroom scale and POMA, bathroom scale and TUG, and bathroom scale and FTBS did not differ statistically between nursing home patients and community-dwelling elderly people. $P$ values of the interaction effect included in each model were $P = .29$, $P = .95$, and $P = .09$, respectively. Controlling for age did not influence these results.

The scatterplots in Figure 2 illustrate how the balance scores on the four tests related to each other in nursing home patients and community-dwelling elderly people.

Discussion

From the results of this study can be concluded that balance measurements with the modified bathroom scale are in line with the results from clinical balance tests. The results also revealed that the bathroom scale confirmed that nursing home patients have poorer balance compared with active community-dwelling elderly people, just as the three clinical balance tests did. These findings suggest that...
the bathroom scale could be a useful tool for measuring balance in elderly people. Previous research has suggested that force plates or balance boards could be used to assess balance. An advantage that the modified bathroom scale has over force plates is that it is much less expensive and easier to use. Also, the bathroom scale can be used in the home instead of a laboratory setting. However, the clinical meaning of the balance scores on the bathroom scale remain to be demonstrated.

Generally, the correlations that were presented in the results were moderate. This is in line with previous studies that have compared clinical balance tests with each other and to force plate measures. Moreover, the correlation between the bathroom scale and the clinical tests were about the same as the correlation between the two clinical tests: the TUG and FTBS. Despite the fact that the correlations between the bathroom scale and the POMA, TUG, and FTBS were significant in nursing home patients and not significant in community-dwelling elderly people, these correlations did not differ statistically between the two groups. This could be due to small group sizes. A possible explanation for the fact that the correlations in the group of community-dwelling elderly people were not significant is that the variation in balance scores on the bathroom scale was much larger compared with the variation on the clinical tests. This ceiling effect was especially evident in the scores of the community-dwelling elderly people on the POMA. Therefore, where clinical tests reach their maximum score, the modified bathroom scale is able to detect variation in balance in community-dwelling elderly people. Whether this additional measurement power is meaningful or is able to detect clinically relevant changes in balance cannot be concluded based on the data that were collected during this study.

The results of the study are based on a single measurement of balance with the modified bathroom scale. Therefore, no conclusions can be drawn regarding test-test reliability. A previous longitudinal study with the modified bathroom scale in community-dwelling elderly people has shown that the reliability of the balance measurements can be greatly improved by using an average score over the course of one week instead of one measurement. The main
reason for this is that the use of only one test from the bathroom scale can increase the variability in the measurements. Despite this, the current study was able to show that a single measurement of balance with the bathroom scale might be as good as a single measurement of balance with a clinical test. However, before the value of the bathroom scale for clinical practice can be determined, test-retest reliability should be investigated.

The overall participation rate in the study was high. An explanation for this might be that measurements that were conducted for the study were embedded in usual daily activities as much as possible. For example, in nursing home patients the balance tests were administered during regular physiotherapy sessions and in community-dwelling elderly people the measurements were conducted during the exercise classes participants attended every week. Besides that, the participating organizations showed commitment and interest in the study.

Despite the fact that the participation rate in nursing home patients and community-dwelling elderly people in this study was high, the sample size was quite small. This could be a limitation of this study; the TUG and FTBS were only conducted in 15 nursing home patients and 17 community-dwelling elderly people. Balance scores may have been influenced by cognitive function because the time it takes a person to step onto the bathroom scale is one of the four parameters that determine the overall bathroom scale balance score. As we did not measure cognitive function in our study, no conclusions can be drawn regarding this. This can be considered a limitation of our study and should be taken into account in future research.

Conclusion

Our results suggest that the modified bathroom scale might be useful for measuring balance in elderly people. Previous research has suggested that poor balance is a relevant predictor for adverse health outcomes.9,27 The modified bathroom scale can be used to measure balance in elderly people and to monitor the development of this predictor over time. Advantages of the modified bathroom scale compared with clinical balance tests are that it is easy for elderly people to perform, that the test can be conducted without professional involvement, and that elderly people can monitor their own balance, which can support self-management. The modified bathroom scale can also support healthcare professionals by transferring data via Bluetooth, which can enable them to monitor the development of balance in their patients from a distance.

The results of this study show that the bathroom scale can detect differences where some clinical tests reach a ceiling effect. At present, it remains difficult to determine whether these differences are clinically relevant or not. Future research should focus on how clinically relevant changes can be detected with the modified bathroom scale. It is also necessary to study the predictive value of balance as measured by the modified bathroom scale on adverse health outcomes such as disability, falls, and hospitalization. Therefore, a longitudinal follow-up study has been planned, which starts in September 2012, during which elderly people will measure their balance daily with the bathroom scale.

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References


