Advs Exp. Medicine, Biology - Neuroscience and Respiration (2016) 21: 63–70
DOI 10.1007/5584_2015_207

Published online: 29 January 2016

Concurrent Validity and Reliability of a New Balance Scale Used in Older Adults

Oz Zur, Tamar Shaki, and Eli Carmeli

Abstract

Adults over the age of 70 are at risk of falling. Various balance tests have been developed to identify balance dysfunctions. Their disadvantages including ceiling effects and low sensitivity and duration led to the development of a new balance test. The present study was conducted to determine the concurrent validity, reliability, sensitivity, and specificity of the Zur Balance Scale (ZBS). In this descriptive, cross-sectional study, 76 senior adults were recruited from an independent senior living community and were administered the Berg Balance Scale (BBS) and the ZBS. The BBS was used as the standard of comparison. The ZBS includes head movements and time to maintain to balance. All the subjects completed the tests. Concurrent validity was $r = 0.782$ ($p < 0.0001$). The ZBS had high intra-test (0.897) and inter-test (0.934) correlation coefficients. Its sensitivity was 60 % and specificity 91 % for identifying falls. The dynamic portions of the ZBS capture the integration of the visual, vestibular, and somatosensory systems, as it mimics dynamic spatial aspects of daily activities. We conclude that the ZBS is reliable compared with BBS. It is a simple, easy to administer test that may predict future risk of falls.

Keywords

Balance • Balance testing • Reliability • Validity • Vestibular

O. Zur (✉)
Department of Physical Therapy, Ben Gurion University of the Negev, Beer Sheva, Israel

The Israeli Center for Dizziness and Balance Disorders, 142 Ahuza St, Ra'anana 4330010, Israel
e-mail: zurbalance@gmail.com

T. Shaki
Department of Physical Therapy, Ben Gurion University of the Negev, Beer Sheva, Israel

E. Carmeli
Department of Physical Therapy, University of Haifa, 199 Aba Khoushy Ave, Haifa, Israel

1 Introduction

Falls among older adults have been associated with hospitalizations, institutionalization, fear of falling, greater risk for future falls, increased dependency, decreased mobility, and early mortality (Roe et al. 2009). The annual incidence of falls in adults over the age of 70 is 1 in 3. The ratio rises to 1 in 2 over the age of 85 (de Castro et al. 2015; Boulgarides et al. 2003). The incidence of vestibular dysfunction increases with age and it is 84 % after age 80 (Agrawal et al. 2009).

Falling is a multifactorial phenomenon with intrinsic and extrinsic features. Balance or gait disorders, dizziness/vertigo, confusion, postural hypotension, visual impairment, and unexpected accidents are among the most common causes (de Castro et al. 2015; Rubenstein 2006; Weiss et al. 2013). Clinicians need tests that can help identify those at risk of falling and that may determine the main factors responsible for the balance limitation in order to choose optimal and early interventions (Horak 1997). Many different methods for measuring balance in older adults, with the goal of predicting values for fallers and non-fallers have been developed with moderate-to-high inter-tester reliability, such as the Berg Balance Scale (BBS) (Berg et al. 1989; La Porta et al. 2012; Muir et al. 2008), the Timed Up and Go Test (Boulgarides et al. 2003), and the Functional Reach Test (Lin et al. 2012). The mini BEST test is a new instrument that includes 14 balance tasks to identify various limitations in postural control (King et al. 2012). Its major advantage lies in a comprehensive approach; yet it lacks specific test conditions for head movements during standing, in order to task the vestibular system. It takes 10–15 min to administer. Likewise, the Modified Clinical Test Sensory Interaction for Balance (mCTSIB) is a well-known test that considers the primary functions for balance. It has four test conditions, but does not include head movements (Park et al. 2013). The Dynamic Gait Index (Whitney et al. 2003) addresses the items related to head movements in the pitch and yaw planes, but these assessments are done while walking.

Similar to other investigations, for the purpose of this study the BBS was chosen to serve as the standard of comparison. The main advantages of the BBS are that it is quick to administer (about 14 min), uses easily-acquired equipment, and involves simple functional tasks. Due to its high reliability and validity, the BBS is used to establish concurrent validity and is often used in research to assess treatment outcomes and as a validation instrument for other balance assessment tools (Langley and Mackintosh 2007; O'Sullivan et al. 2009; Geiger et al. 2001). The BBS is reproducible and has good inter-tester reliability (La Porta et al. 2012). The test is more appropriate for participants with moderate-to-severe balance dysfunction. Yet a drawback of the BBS is that it has a fairly low sensitivity to detect change in a patient's balance over time. It also has a ceiling effect (Stevenson 2001), although less so than other balance scales, such as the Performance-Oriented Mobility Assessment Tool or the Dynamic Gait Index (Pardasaney et al. 2012; Whitney et al. 2003).

The Zur Balance Scale (ZBS) is a new tool designed to evaluate balance. It measures the effects of the three main sensory systems (visual, vestibular, and somatosensory) operating together to maintain balance. Horizontal and vertical head movements are used specifically to assess the dynamic aspects of the vestibular system. The ZBS measures balance while the participant is standing on a firm surface or a half cylinder of styrofoam, in the tandem or Romberg position. It takes only 4–5 min to administer and uses simple, easily-acquired equipment.

The purpose of this study was to determine the concurrent validity, reliability, and sensitivity and specificity (i.e., to predict future falls) of the ZBS by comparing it with the BBS. The ZBS includes head movements while standing in varied positions on different surfaces.

2 Methods

2.1 Zur Balance Scale (ZBS)

The present study was approved by the Institutional Review Board of Maccabi Health Maintenance Organization (permit no. 14/2014). All participants provided written, informed consent.

The ZBS is a screening test for assessing balance function. It is quick (4–5 min) and simple to administer and analyze. Equipment needed for the test is a half-cylinder of styrofoam 60 cm long × 18 cm wide × 9 cm high, a stop watch for measuring time in seconds, and a metronome set at one Hz. The styrofoam has a density of 30 kg/m^3 and is covered tightly with a stretchable piece of fabric. The ZBS should be conducted in a quiet room. The tested participant is asked to stand 2 m from the fixed target, a 5 × 5 cm X mark at the eye level (±30°). A solid support (such as a chair or table) is placed next to the participant for safety and confidence, while the examiner stands in front of the participant, to the side. Participants are asked to stand consecutively in Romberg or tandem stance on the floor or on the styrofoam while completing a series of four different tasks (eyes open, eyes closed, horizontal head movements, and vertical head movements).

Each combination of stance and task comprises a different condition, for a total of ten conditions evaluated. The ability to maintain balance for a maximum of 10 s is measured for each condition. The test begins with the participant standing stable on the floor. This can be achieved with a support on one side and the examiner on the other. The test is started with participant's hands on his/her hips, when the participant is ready. Each condition is performed twice and the better of the two is recorded for analysis.

The ZBS is scored by counting the number of head movements (HM) and time to maintain balance. The time to maintain balance (with and without HM) is measured in seconds, for a maximum of 10 s (Table 1, black boxes indicate time without head movements). In 5 of the 10 conditions (2, 3, 6, 8, 10; white boxes), the participant is asked to move his/her head left and right covering an arc of approximately 120° (60° to each side) and a total of 60° up and down (30° up and 30° down), each within 10 s according to a 60 Hz metronome. From 0 to 10 HM are performed in each condition, for a maximum of 50. The ZBS score is calculated by summing the total number of HM multiplied by 2, plus the total time (in seconds) divided by 2.

Table 1 Zur Balance Scale – score sheet

Condition	Task	Abbreviation	Head motion	Time (s)
1	Romberg stance on the floor, eyes closed	(ROM_EC)		
2	Romberg stance on the floor, during horizontal head movements, eyes closed	(ROM_HM)		
3	Romberg stance on the floor, vertical head movements, eyes closed	(ROM_VM)		
4	Tandem stance on the floor, with eyes open on a fixed target	(TAN_EO)		
5	Tandem stance on the floor, eyes closed	(TAN_EC)		
6	Tandem stance on the floor, during horizontal head movements	(TAN_HM)		
7	Romberg stance on styrofoam, eyes open on a fixed target	(S_ROM_EO)		
8	Romberg stance on styrofoam with vertical head movements, eyes open	(S_ROM_VM)		
9	Tandem stance on styrofoam, with eyes open on a fixed target	(S_TAN_EO)		
10	Tandem stance on styrofoam, with horizontal head movements, eyes open	(S_TAN_HM)		
Total	Score Calculation		(Head movements× 2) Max = 100	Sum of sec Max = 100

ROM Romberg stance, *EC* eyes closed, *EO* eyes open, *HM* horizontal head movements, *VM* vertical head movements, *TAN* Tandem stance, *S_ROM* Romberg stance on Styrofoam, *S_TAN* Tandem stance on styrofoam

The BBS was conducted according to the protocol described by Berg et al. (1989).

2.2 Study Protocol

In this descriptive, cross-sectional, double blind study, 300 older adults residing in an independent living community were invited to participate in a lecture entitled ‘Balance and Falls’. They were introduced to the ZBS and to the BBS. Inclusion criteria were age 70 years or over and ability to walk independently, with or without a cane. Following the lecture, 110 volunteered to participate in the study and signed a consent form. A total of 76 subjects of the mean age of 83 ± 5 years, range 71–97 years, met the inclusion criteria. Sixty of them (79 %) were female. The participants lived in the independent senior living community for a mean of 3 ± 1.5 years. They had an average of 12 ± 3 years of education and were engaged in sport activities for a median of 3 h a week.

Sociodemographic data were collected including date of birth, gender, fall history, fall-related injury, physical exercise activity, social activity, and the length of residence in the facility. Exclusion criteria included assistive device for standing, a static visual deficit (i.e., unable to read at least the first five lines on the Snellen eye chart even with vision correction), cognitive deficit (Mini-Mental State Examination score of less than 24), neurological condition (such as Parkinson’s disease or cerebrovascular accident), or acute orthopedic conditions (such as hip fracture).

Participants were randomly administered the ZBS and the BBS on the same day (T1) by two experienced clinical physical therapists. One physical therapist administered the ZBS (tester 1) and another administered the BBS (tester 2) to evaluate the validity of the ZBS. For reliability testing, the ZBS was readministered by the same physical therapist, under the same conditions (i.e., time of day and place) 10 days later (T2). In addition, to evaluate inter-tester reliability, the ZBS was also administered by a third, experienced clinical physical therapist (first author). Thus, each participant was tested twice at T2 and the order of the therapists also was randomized.

The medical staff of the independent living community maintains strict fall monitoring and surveillance policies. Falls during the 18 months after the balance examinations were collected from the medical records as documented in a report by the faller or by a significant other, usually the medical staff. This follow-up information was used to determine the cut-off point for the likelihood of falling (see the section on sensitivity and specificity for fall prediction below).

2.3 Statistical Analysis

Two previous studies that compared new balance tests to the BBS were used to determine the minimum sample size (Langley and Mackintosh 2007; Whitney et al. 2003). Based on the numbers reported in those studies, we planned to enroll a minimum of 70 participants (Roe et al. 2009).

The BBS score was converted into a percentage and the ZBS was measured on a numerical scale from 0 to 100 in order to have comparative scales. The BBS was used as the standard for establishing concurrent validity. Concurrent validity of the ZBS was assessed against the BBS with Pearson’s correlation of the ZBS against the BBS. Test-retest in two different sessions and inter-tester reliability were assessed using intra-class correlations ICC.

Receiver operating characteristic (ROC) was used to determine the cut-off scores of the BBS (not presented) and the ZBS between fallers and non-fallers. Specificity and sensitivity were calculated. Differences between nominal parameters and fall status were calculated using the Chi-squared test. Differences between continuous variables were calculated using a *t*-test. $P < 0.05$ was considered statistically significant. All analyses were performed using IBM, SPSS-22 software.

3 Results

During the follow-up of testing, 13 participants (17 %) experienced a fall (eight had one fall and five had at least two falls). There were no statistical differences in the background parameters of age, gender, years of education, years of residence in the facility for seniors, or exercise activity between fallers and non-fallers.

3.1 Concurrent Validity, Intra-tester Reliability, and Inter-tester Reliability

The mean ZBS score was 55 ± 12.8 (min 6, max 82, median 56). The mean BBS score was 87 ± 13.2 (min 7, max 100, median 91). Validity was indicated by Pearson's correlation between the ZBS and the BBS ($r = 0.682$, $p < 0.0001$) (Fig. 1).

The ZBS was administered twice by the same tester at 10–14 day intervals to evaluate intra-session reliability. In addition, the ZBS was randomly administered by a third tester to evaluate inter-tester reliability. The intra-tester reliability ICC was 0.934 (95 % CI = 0.904–0.956) and inter-tester reliability ICC was 0.934 (95 % CI = 0.904–0.956).

3.2 Sensitivity and Specificity for Fall Prediction

The ROC curve was used to find the cut-off score of the ZBS to predict falls (Fig. 2). The cut-off point was 0.56 as an optimal point to predict falls. The area under the curve was 0.755, (95 % CI = 0.615–0.895). For comparison, the cut-off point of the BBS was 0.90. Both BBS and ZBS were used to predict an individual's faller status. The ZBS's sensitivity was 60 % and specificity was 91 %. The BBS's sensitivity was 66 % and specificity was 91 %.

4 Discussion

The purpose of this cross-sectional study was to determine the concurrent validity, reliability, and sensitivity and specificity of the Zur Balance Scale (ZBS), a new scale to evaluate dynamic vestibular function among older adults. The ZBS was developed over several years based on a content validity assessment process among 30 experienced physical therapists, researchers, and neuroethology physicians and 20 years of experience working with thousands of individuals with dizziness and balance disorders. A half-cylinder of styrofoam was used for 4 of

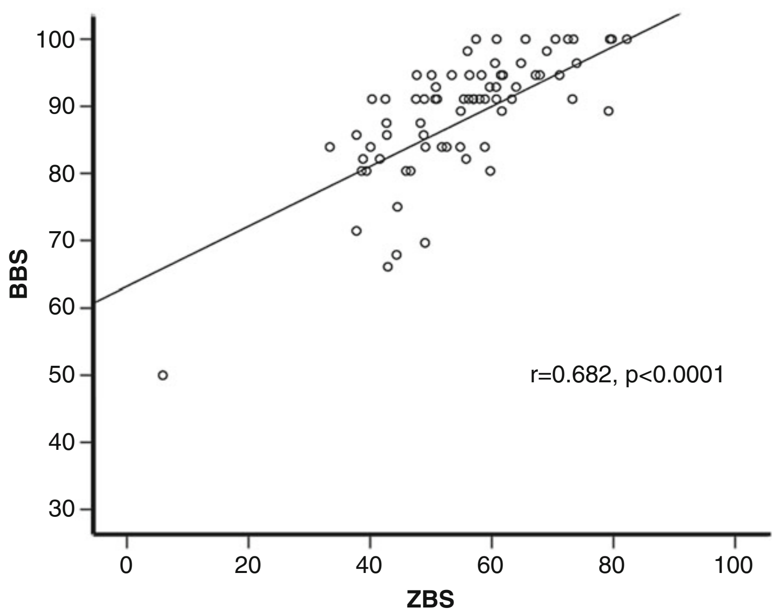
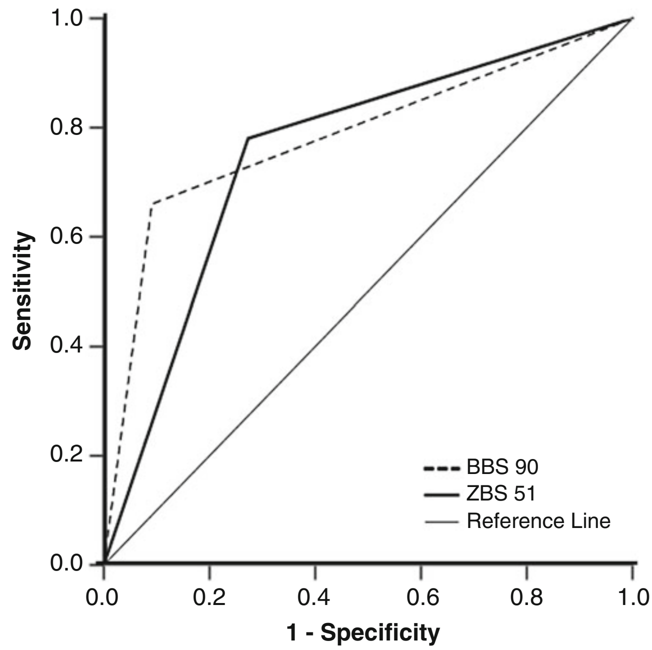


Fig. 1 Concurrent validity between Berg Balance Scale (BBS) and Zur Balance Scale (ZBS)

Fig. 2 Receiver operating curves (ROC) for Berg Balance Scale (BBS) and Zur Balance Scale (ZBS)



the 10 items on the ZBS to alter somatosensory input. The cylinder's length and width were chosen to suit the foot size of most people and the height to maintain safety.

To assess the concurrent validity of the ZBS, the scale had to be compared with a well-known, validated, and reliable test, such as the BBS. The BBS is usually the first choice for assessing balance among older adults (Berg et al. 1989; La Porta et al. 2012). We chose not use the Mini BESTest, even though it includes horizontal and vertical head movements, but does so only while walking. We did not use the mCTSIB either, since it does not include head movements at all.

The results demonstrate that in some aspects the ZBS is as good as the BBS for evaluating older adults. As a new balance test, the ZBS is important because it includes horizontal and vertical head movements during different stances, whereas other balance tests do not consider head motions while standing still. The Fullerton Advanced Balance Scale (Rose et al. 2006) and the Dynamic Gait Index (Whitney et al. 2003) request participants to perform head movements during gait examination. The assessment of a static balance with head movements is indispensable, since this evaluates the sensory systems involved in maintaining balance (Malstrom et al. 2007).

The ZBS was found to be as reliable as the BBS in intra-session reliability and inter-tester reliability. Both tests are both important tools for therapists assessing balance. However, the added value of ZBS is that it focuses on the dynamic function of the vestibular system. Thus, vestibular impairments may be more easily identified by using ZBS.

A few limitations to the study should be noted. We did not perform logistic regressions with other interacting variables, such as the level of physical activity, medications used, and comorbidities. One possible weakness of this study might be using the styrofoam for 4 of the 10 items. Styrofoam might have a potential to reduce foot contact; thereby introducing a confounding variable, i.e., increased requirement for a hip strategy to control one's center of mass over the base of support. Therefore, future studies may also compare ZBS with mCTSIB on a force plate. We also found a lower proportion of fallers (17 %) than would be expected. Despite the fact that a fall monitoring and surveillance program was rigorously managed, this low frequency of fall events might suggest that mainly falls with injuries were recorded and some minor falls might have been missed.

We believe that older adults with a feeling of imbalance should be evaluated by ZBS, and not by BBS which does not include measures that stress vestibular function. Since vestibular dysfunction is common among older adults, the ZBS should be administered first. On the other hand, BBS should be the first choice for assessing older adults with severe balance deficits, since many of the test conditions are easier to perform compared to ZBS. In our opinion, ZBS should be the first choice for independent older adults. After 18 months of follow-up of falls in the study population, the ZBS seems to be a sensitive test for detecting balance dysfunction and predicting falls.

In conclusion, ZBS is potentially equivalent to BBS for balance assessment. The ZBS highlights the integration of the three main sensory systems involved in maintaining balance. Specifically, it mimics the dynamic, spatial aspects of daily activities such as standing on an uneven surface with voluntary head movements. In addition, ZBS is quick to administer and the score is easy to calculate on a 0–100-point scale. The ZBS can be used to assess participants before, during and after vestibular rehabilitation.

Acknowledgements The author would like to thank Profs. Cortney Hall and Michael Shubert for their comments on the previous files. Special thanks go to the physical therapists Yakir Ariam and Yair Ohel who performed the examinations and to the professional staff of Beit Ildan. The manuscript was edited by Faye Schreiber. Nava Jelin performed the statistical analysis.

Conflicts of Interest This study was not supported by external funding. The authors have no conflicts of interest to declare.

References

Agrawal Y, Carey JP, Della Santina CC, Schubert MC, Minor LB (2009) Disorders of balance and vestibular function in US adults: data from the National Health and Nutrition Examination Survey, 2001–2004. Arch Intern Med 169(10):938–944

Berg K, Wood-Dauphine S, Williams JI, Gayton D (1989) Measuring balance in the elderly: preliminary development of an instrument. Physiother Can 41(6):304–311

Boulgarides LK, McGinty SM, Willett JA, Barnes CW (2003) Use of clinical and impairment-based tests to predict falls by community-dwelling older adults. Phys Ther 83(4):328–339

de Castro V, Mokoroa O, Artieda J, Muniozguren N, Etxebarriarteun L, Alvarez L, Garcia Calabuig MA, Red de MédicosVigía del País Vasco (2015) Epidemiology of accidents in a cohort of adults over 64 years old in the Autonomous Community of the Basque Country. Rev Esp Geriatr Gerontol 50(6):281–284 (Article in Spanish)

Geiger AG, Allen JB, O'Keefe J, Hicks RR (2001) Balance and mobility following stroke: effects of physical therapy interventions with and without biofeedback/forceplate training. PhysTher 81(4):995–1005

Horak FB (1997) Clinical assessment of balance disorders. Gait Posture 6(1):76–84

King LA, Priest KC, Slarin A, Pierce D, Horak FB (2012) Comparing the Mini-BESTest with the Berg Balance Scale to evaluate balance disorders in Parkinson's disease. Park Dis 2012:375–419

La Porta F, Caselli S, Susassi S, Cavallini P, Tennant A, Franceschini M (2012) Is the Berg Balance Scale an internally valid and reliable measure of balance across different etiologies in neurorehabilitation? A revisited Rasch analysis study. Arch Phys Med Rehabil 93 (7):1209–1216

Langley FA, MacKintosh SFH (2007) Functional balance assessment of older community dwelling adults: a systematic review of the literature. Internet J Allied Health Sci Pract 5(4):1–11

Lin YH, Chen TR, Tang YW, Wang CY (2012) A reliability study for standing functional reach test using modified and traditional rulers. Percept Mot Skills 115 (2):512–520

Malstrom EM, Karlberg M, Melander A, Magnusson M, Moritz U (2007) Cervicogenic dizziness-musculoskeletal findings before and after treatment and long-term outcome. Disabil Rehabil 29 (15):1193–1205

Muir SW, Berg K, Chesworth B, Speechley M (2008) Use of the Berg Balance Scale for predicting multiple falls in community-dwelling elderly people: a prospective study. Phys Ther 88(4):449–459

O'Sullivan M, Blake C, Cunningham C, Boyle G, Finucane C (2009) Correlation of accelerometry with clinical balance tests in older fallers and non-fallers. Age Ageing 38(3):308–313

Pardasaney PK, Latham NK, Jette AM, Wagenaar RC, Ni P, Slavin MD, Bean JF (2012) Sensitivity to change and responsiveness of four balance measures for community-dwelling older adults. Phys Ther 92 (3):388–397

Park MK, Kim KM, Jung J, Lee N, Hwang SJ, Chae SW (2013) Evaluation of uncompensated unilateral vestibulopathy using the modified clinical test for sensory interaction and balance. Otol Neurotol 34 (2):292–296

Roe B, Howell F, Riniotis K, Beech R, Crome P, Ong BN (2009) Older people and falls: health status, quality of life, lifestyle, care networks, prevention and views on service use following a recent fall. J Clin Nurs 18 (16):2261–2272

Rose DJ, Lucchese N, Wiersma LD (2006) Development of a multidimensional balance scale for use with functionally independent older adults. Arch Phys Med Rehabil 87(11):1478–1485

Rubenstein LZ (2006) Clinical risk assessment, interventions and services: falls in older people: epidemiology, risk factors and strategies for prevention. Age Ageing 35(2)-S2, ii37–ii41

Stevenson TJ (2001) Detecting change in participants with stroke using the Berg Balance Scale. Aust J Physiother 47(1):29–38

Weiss A, Brozgol M, Dorfman M, Herman T, Shema S, Giladi N, Hausdorff JM (2013) Using 3-day accelerometer recordings. Does the evaluation of gait quality during daily life provide insight into fall risk? A novel approach. Neurorehab Neural Repair 27 (8):742–752

Whitney S, Wrisley D, Furman J (2003) Concurrent validity of the Berg Balance Scale and the dynamic gait index in people with vestibular dysfunction. Physiother Res Int 8(4):178–186