Physical Therapy
Journal of the American Physical Therapy Association and de Fysiotherapeut
Royal Dutch Society for Physical Therapy

PTJ Online First

Increasing the Clinical Utility of the BESTest, Mini-BESTest, and BriefBESTest: Normative Values in Canadian Adults Who Are Healthy and Aged 50 Years and Over

Sachi O'Hoski, Bonnie Winship, Lauren Herridge, Taimoor Agha, Dina Brooks, Marla K. Beauchamp and Kathryn M. Sibley

PHYS THER. Published online October 3, 2013
doi: 10.2522/ptj.20130104

Research Report

Increasing the Clinical Utility of the BESTest, Mini-BESTest, and BriefBESTest: Normative Values in Canadian Adults Who Are Healthy and Aged 50 Years and Over

Sachi O'Hoski, Bonnie Winship, Lauren Herridge, Taimoor Agha, Dina Brooks, Marla K. Beauchamp, Kathryn M. Sibley

S. O'Hoski, Department of Physical Therapy, University of Toronto, and Department of Respiratory Medicine, West Park Healthcare Centre, Toronto, Ontario, Canada.

B. Winship, Department of Physical Therapy, University of Toronto.

L. Herridge, Department of Physical Therapy, University of Toronto, and Southlake Regional Health Centre, Newmarket, Ontario, Canada.

T. Agha, Department of Physical Therapy, University of Toronto.

D. Brooks, Department of Physical Therapy, University of Toronto; West Park Healthcare Centre; and Toronto Rehabilitation Institute–University Health Network.

M.K. Beauchamp, Department of Physical Therapy, University of Toronto; West Park Healthcare Centre; and Harvard Medical School, Cambridge, Massachusetts.

K.M. Sibley, Department of Physical Therapy, University of Toronto, and Toronto Rehabilitation Institute–University Health Network, 550 University Ave, Room 11-173, Toronto, Ontario, Canada M5G 2A2. Address all correspondence to Dr Sibley at: kathryn.sibley@uhn.ca.

[O'Hoski S, Winship B, Herridge L, et al. Increasing the clinical utility of the BESTest, Mini-BESTest, and BriefBESTest: normative values in Canadian adults who are healthy and aged 50 years and over. *Phys Ther.* 2014;94:xxx–xxx.]

Published Ahead of Print: XXX
Accepted: October 1, 2013
Submitted: March 9, 2013

Background. Balance is a composite ability requiring integration of multiple systems. The Balance Evaluation Systems Test (BESTest) and two abbreviated versions (the mini-BESTest and briefBESTest) are balance assessment tools that target these systems. To date, no normative data exist for any version of the BESTest.

Objective. The purpose of this study was to determine the age-related normative scores for the BESTest, mini-BESTest and briefBESTest for healthy Canadians between the ages of 50 and 89.

Design. A cross-sectional study design was used.

Methods. Seventy-nine healthy adults aged 50 to 89 participated (mean age 68.9 years; 50.6% female). Normative scores were reported by age decade.

Results. Mean BESTest scores were 95.7 (95% CI 94.4 - 97.1) for adults ages 50-59, 91.4 (89.8 - 93.0) for ages 60-69, 85.4 (82.5 - 88.2) for ages 70-79 and 79.4 (74.3 – 84.5) for ages 80-89. Similar results are reported for the mini and brief with all three tests showing statistically significant differences in scores between the age cohorts ($p < 0.001$).

Limitations. As we only tested participants from age 50 to 89, there are still no normative data for individuals outside of this age range. Also, the scores presented may not be generalizable to all countries.

Conclusions. This normative data enhances the clinical utility of the BESTest, mini-BESTest and briefBESTest by enabling clinicians to use these values as reference points to guide treatment.

Approximately one third of community-dwelling individuals over the age of 65 fall each year.[1] Falls are associated with increased morbidity and mortality as well as high healthcare costs.[2] Many risk factors for falls have been identified, and one important modifiable risk factor is a deficit in balance.[3-6] Defined as the ability to maintain the body's centre of mass over its base of support, balance is not a stand-alone skill; it is a composite ability involving rapid, automatic anticipatory and reactive integration of information from several systems.[7,8] Many of the components that contribute to balance, such as strength and sensation, are impaired in the elderly.[3,4,6,9] Therefore, appropriate clinical assessment tools are necessary to screen for balance impairments.

Commonly used functional balance tests, including the Berg Balance Scale (BBS)[10] and the Timed Up and Go (TUG),[11] have been designed to identify balance problems and predict fall risk.[10,12-14] However, few balance tests have been developed to identify the underlying systems responsible for the balance deficits. An understanding of the systems underlying the deficits in postural control is critical for diagnosing specific impairments and developing individualized treatment plans.[8] The Balance Evaluation Systems Test (BESTest) is a recently developed standardized functional balance tool that is aimed at identifying the contributing components to dysfunctional balance; it targets six postural control subsystems (see Table 1).[15] The BESTest has been shown to have high inter-rater reliability, high test-retest reliability and very good validity in people with Parkinson's Disease (PD).[16] Performance on the BESTest has been shown to discriminate between fallers and non-fallers with PD[16,17] and between the impairments associated with several clinical diagnoses including PD and vestibular dysfunction.[15] The BESTest has also been used in people with cerebral palsy, peripheral neuropathy, total hip replacements, fibromyalgia and chronic obstructive pulmonary disease.[15,18-20]

Despite its validation and published findings, the BESTest is not often used in clinical practice.[21] This may be due to the administration time which has been reported to range from 20 to 60 minutes,[15,22] which may not be feasible in all clinical settings. Accordingly, an abbreviated version of the BESTest was developed as a brief test of dynamic balance that can be administered in less than half the time of the full BESTest.[23] The mini-BESTest consists of 14 out of the 36 items from the original BESTest but the items are scored differently, on a 3 point rather than 4 point scale.[23,24] Scores on the mini-BESTest have been shown to correlate well with total BESTest scores,[17] balance confidence,[24] and the BBS in people with PD.[25,26] It has also been shown to have high inter-rater and test-retest reliability.[17] The mini-BESTest has been used to test balance in people with stroke, multiple sclerosis, vestibular disorders, and traumatic brain injury[23] and, like the BESTest, it has been shown to discriminate between fallers and non-fallers in people with PD.[17]

While the mini-BESTest fulfills the need for a shorter version of the BESTest, it only gives a total score of dynamic balance and does not identify the underlying system(s) of impairment. Another shortened version, the briefBESTest[22] was developed in order to maintain the theoretical basis of the original test. Padgett and colleagues examined the internal consistency of each item of the BESTest and used item-total correlations to identify each subsection's most representative item.[22] The resulting "briefBESTest" consists of one item from each section of the original BESTest with two items (the single leg stance and functional reach forward) scored bilaterally. In preliminary testing, the briefBESTest was shown to have comparable inter-rater reliability to the BESTest and mini-BESTest and superior accuracy to the other tests in identifying fallers and non-fallers with and without a neurological diagnosis.[22]

A small number of studies have used the BESTest in healthy control participants[15,19,20] however, the small sample sizes in these studies (ranging between 3 and 32 participants), as well as the failure to report scores based on age, limit the generalizability and interpretation of scores achieved by these patients. To date, no normative BESTest, mini-BESTest or briefBESTest data have been published. The ability to compare patients' scores on the BESTest, mini-BESTest and briefBESTest to a range of expected scores for a healthy age-matched population will be meaningful for clinicians and patients as it will provide a relative indication of balance performance and help to guide treatment goals. Thus, the primary objective of this study was to determine the age-related normative scores for the BESTest, mini-BESTest and briefBESTest for healthy Canadians between the ages of 50 to 89. We hypothesized that balance scores would differ significantly between age groups.

METHODS

This study was approved by the Research Ethics Board at the University of Toronto. Written informed consent was obtained and a copy of the consent form was provided to each participant. A cross-sectional study design was used.

Participants

Healthy community-dwelling older adults between the ages of 50 and 89 years were recruited through local advertisement in community centers, hospitals, and universities. Consistent with previous studies that reported normative scores,[27,28] we targeted a sample size of 80 participants (10 males and 10 females in each decade between 50 and 89 years). Assignment to age cohort was determined by the participants' chronological age at the time of testing.

Interested participants were screened over the telephone to determine eligibility for the study. Individuals were included if they met the following criteria: (1) age 50-89, (2) living independently in the community, (3) able to speak and read English, (4) able to follow 3-step commands, (5) able to provide written informed consent and (6) able to ambulate 6 meters independently without a gait aid. Individuals were excluded if they reported (1) a history of dizziness or fainting, (2) a past or current history of either a cardiorespiratory, neurological or musculoskeletal impairment that affected their balance, and (3) current use of any medication(s) that cause dizziness or impair balance (e.g., psychotropic medications).

Procedure

Each data collection session was completed within one 60-minute period in a quiet laboratory setting at the University of Toronto between January and July 2012. Participants were instructed to wear comfortable, flat shoes. Demographic data, including sex, age, height, and weight were collected prior to administration of the BESTest.

Four members of the research team who were Masters of Physical Therapy students (SO, BW, LH, and TA) were trained to administer and score the BESTest by first observing the BESTest training DVD[29] and then by undergoing training with a registered physical therapist (MB) with extensive experience administering the test. In order to reduce errors in inter-rater reliability, all four testers scored the first four participants. The scores for each item on the BESTest were then compared to ensure consistency of ratings. When discrepancies in scoring were evident the testers discussed their rationales for the score chosen and came to a unified conclusion on how to score future attempts for problematic tasks.

Two of the four testers were present for each testing session. For each item on the BESTest, one tester read the standardized instructions[29] to the participant while the second tester completed a demonstration of the task. The participant then attempted the task with close supervision provided by the second tester to ensure participant safety. If the participants' attempt indicated an obvious misunderstanding of the instructions another demonstration was given and the participant was allowed a second attempt at the task. Each task was scored immediately after completion and participants were provided with a verbal summary of their BESTest results at the end of the session. Scoring of the mini-BESTest and briefBESTest occurred after completion of all testing sessions based on the performance of the BESTest tasks; participants did not complete the mini-BESTest or briefBESTest tasks separately. All scores were calculated by the testers (two of SO, BW, LH and TA) and verified by the other two at the time of data entry.

Outcome Measures

Balance Evaluation Systems Test (BESTest)[15]

The BESTest consists of 36 items grouped into the aforementioned six categories (see Table 1). Each task is scored on an ordinal scale between 0 and 3 as judged by time or performance criteria. The overall BESTest score is a sum of all the individual items resulting in a maximum score of 108 points. Scores are converted to percentages with a higher score indicating better balance performance. Materials needed to administer the BESTest, including a 10 degree incline ramp, a 60cm x 60cm block of 4", medium-density Tempur® foam and the BESTest training DVD were purchased from the BESTest website.[29] All other materials utilized were in accordance with the BESTest written standards. The stair height was measured at 17 cm and the obstacle (two stacked shoeboxes) height was measured at 25 cm. A 5-lb plate was used for the lifting item in the stability limits and verticality section.

Mini-BESTest[23]

The mini-BESTest includes 14 items from the BESTest, from four out of the six subsections. It includes three tasks from 'anticipatory postural adjustments', three tasks from 'postural responses', three tasks from 'sensory orientation' and five tasks from 'stability in gait'.

It does not include any items from 'biomechanical constraints' or 'stability limits/verticality' as the items from these subsections were not deemed to measure dynamic balance. Items are scored from 0-2 and then summed to obtain a total score out of a possible 28 points.[24] A higher score indicates better balance performance.

BriefBESTest[22]

The briefBESTest was created using six items from the BESTest, one from each subsection, with two items (single leg stance and functional reach forward) scored bilaterally, resulting in an eight item test. Like the BESTest, items are scored from 0-3 and then summed to obtain a total score out of a possible 24 points. A higher score indicates better balance performance. As this test was created by compiling the most statistically representative item from each subsection of the BESTest, each item provides its own subscore.

Data Analysis

Descriptive statistics (mean, SD, 95% CI) were calculated for age, height, weight, body mass index, BESTest (total and subscores), mini-BESTest, and briefBESTest (total and subscores). Box plots were used to show the median, minimum and maximum values and 25th-75th percentiles for the BESTest, miniBESTest and briefBESTest total score for each age cohort. Both graphical and statistical methods (Shapiro-Wilk test) were used to determine normality. Because the data were not normally distributed, Kruskal-Wallis analyses were used to determine whether balance scores differed significantly across age groups within each of the balance tests. All statistical analyses were conducted using SPSS software (version 19.0 for Windows; SPSS Inc.; Chicago, United States).

RESULTS

The targeted sample size (n = 10) was achieved in all age and gender cohorts except for males 80-89 (n = 9), resulting in a total sample size of 79 individuals. Descriptive characteristics of the participants are given in Table 2. Mini-BESTest scores are missing for one male in the 50-59 year cohort and two males in the 60-69 year cohort due to differences in scoring of the BESTest and mini-BESTest. A score of 2 points on item 20 in the 'sensory orientation' section of the BESTest could correspond with either a score of one or two on item 9 in the mini-BESTest; these three tests were not included in the analyses. Table 3 presents the normative scores for the BESTest (total and subscores), mini-BESTest and briefBESTest (total and subscores) for each age cohort. Figures 2, 3, and 4 illustrate the boxplots for each tests' total score. Mean total scores decreased with age for all three tests. The Kruskal-Wallis analyses showed significant differences across age groups on the BESTest (chisquare = 47.990, df = 3, $p < 0.001$), mini-BESTest (chisquare = 41.662, df = 3, $p < 0.001$) and briefBESTest (chisquare = 37.608, df = 3, $p < 0.001$) as well as all subscores of the BESTest and BriefBESTest (see Table 3).

DISCUSSION

This study provides BESTest, mini-BESTest and briefBESTest scores for a representative cohort of healthy community-dwelling older adults, and fills a gap in the literature since no normative data previously existed for these measures. Results from our study can be used by clinicians to guide interpretation of balance scores on the BESTest, mini-BESTest and briefBESTest. Furthermore, our data support our hypotheses that BESTest, mini-BESTest and briefBESTest scores would decrease with age.

In this study, we found that balance scores showed a significant decline with age which we expected based on previous work.[28,30] Isles and colleagues[30] found that balance performance, as measured by the TUG, the Step Test, the Functional Reach Test, and the Lateral Reach Test, gradually declined with age in community-dwelling, independently mobile women aged 20 to 80. Similarly, Steffen and colleagues[28] demonstrated a consistent trend for scores on the BBS and TUG to decline with age in community-dwelling older adults.

Three previous studies used the BESTest for measuring balance in healthy participants. However, their data was intended for comparison with patients with a variety of health conditions, rather than with the specific purpose of obtaining normative scores that could be used as a reference for clinicians.[15,19,20] As such, the sample sizes of the healthy control groups in these studies were small and the authors did not provide scores based on age decade. Overall mean BESTest scores in prior work ranged from 90.6% (for subjects with a mean age of 65.7 years)[15] to 95.6% (for subjects with a mean age of 46.5 years).[19] These scores are similar to the scores we obtained for the corresponding age groups (95.7% for participants with mean age 55.5 years and 91.4% for participants with mean age 63.5 years).

Visual inspection of the box plots suggested that there was a considerable increase in the variation across balance scores with age. Further, while the variation in BESTest scores of our participants aged 50-69 years (SD ranged from 1.4 to 3.9) is similar to that reported in other studies (SD from 2.9 to 4.8),[15,19,20] we found a higher variation in scores in older participants (SD from 4.6 to 10.8 in the cohorts aged 70 years and older). This could be due to the fact that we did not control for participants' activity level which is known to relate to balance and to change with age.[31,32] We also did not control for the presence of comorbidities that were not thought to affect balance and it is likely that our older participants had an increased number of comorbidities.[33] However, other normative studies of balance measures such as single leg stance (SLS),[34] BBS and TUG,[28] and lateral and forward reach, have not yielded similar results.[30] Another possibility is that, due to the variety of tasks included in the BESTest, it was able to detect a wider variety of impairments than other balance measures. This increased variability in BESTest, mini-BESTest and briefBESTest scores seen with age needs to be examined further.

Our findings fill an important knowledge gap that may facilitate uptake of the BESTest, mini-BESTest and/or the briefBESTest by clinicians. A recent survey found that the top three most commonly used balance measures among Ontario physiotherapists are the SLS, BBS, and TUG,[21] all measures with normative data.[28,34] The reference data we provide based on age decade for BESTest , mini-BESTest and briefBESTest scores will allow more widespread use of these tests, which are some of the only tools available that enable clinicians to distinguish among specific subsystems contributing to impaired balance. This knowledge is essential to allow clinicians to tailor treatment to target the specific deficits underlying the observed balance limitations in their patients.

Limitations and Future Directions

A limitation of the current study is that it may not be generalizable as we only tested 79 Canadians between 50 and 89 years of age. Normative scores for individuals outside of this age range still do not exist. In addition, while our sample is representative of a healthy community-dwelling cohort living in an urban area of Ontario, Canada, our results may not be reflective of populations in other countries. Furthermore, males in the 80-89 year cohort had a mean age of 82.3 years and a sample size of 9. The difficulty in recruitment for this cohort could be due to the increased number of co-morbidities present in older individuals[32] affecting eligibility for the current study. Future studies including the administration of this test in healthy populations should aim to have larger sample sizes and to recruit participants across the lifespan and from a variety of countries.

A second limitation of the study pertains to our inclusion and exclusion criteria that were reliant solely on the participant's self-report of his/her own medical status. A more rigorous screening process that involved medical examination or chart review may have increased the likelihood of finding 'healthier' older adults and led to an observation of higher scores on the balance tests. However, stricter criteria would have decreased the external validity of our findings.

A third limitation of our study is that, while we found that scores on all balance tests differed significantly between age groups, it was beyond the scope of this paper to perform post-hoc analyses to determine where those differences exist. While a trend for scores to decrease with age is demonstrated visually in figures 1-3, further exploration is required.

While we took extra precautions to ensure consistency of scoring amongst testers for this study, the training DVD that is available from the BESTest website[29] is a comprehensive training tool that should be used by clinicians prior to adopting this test as an outcome measure. Repeated administration of the BESTest highlighted one issue that clinicians should be aware of when interpreting the score for 'stability in gait'. The scores in this subsection were the lowest of all the sections for the majority of our age groups; we hypothesize this may be due to difficulties with the last item, the dual-task TUG. Participants in all age cohorts struggled with counting backwards by three even before adding the secondary physical task, suggesting that this particular cognitive dual-task item may have been too difficult to distinguish among people with different levels of deficits. This observation is supported by Padgett and colleagues[22] who found that the dual-task TUG item was the least representative item in the entire BESTest. Simplifying the cognitive task to counting backwards by two or inclusion of a manual dual-task TUG[35] may be better alternatives to the current cognitive dual-task TUG, which can be influenced by practice and one's familiarity with numbers.

In summary, our study is the first to provide normative values for healthy older adults on the BESTest, mini-BESTest and briefBESTest which may enhance the utility of these tools as comprehensive measures of balance for clinicians to use with a wide variety of patients. Further research should focus on the predictive validity, reliability and responsiveness of these tests in healthy populations as well as examine the relationship between balance scores and physical activity level in this population.

All authors provided concept/idea/research design, writing, and data analysis. Ms O'Hoski, Ms Winship, Ms Herridge, Mr Agha, and Dr Beauchamp provided data collection. Ms O'Hoski, Ms Ms Herridge, Ms Brooks, Dr Beauchamp, and Dr Sibley provided project management. Ms Brooks provided fund procurement, facilities/equipment, and institutional liaisons. Ms O'Hoski, Ms Winship, Ms Herridge, and Dr Beauchamp provided study participants. Ms Winship, Ms Herridge, Mr Agha, and Dr Beauchamp provided consultation (including review of the manuscript before submission). The authors acknowledge the assistance of Mike Sage in establishing the protocol for this study and thank all the participants for their time.

A portion of the data was presented at the Canadian Physiotherapy Association Congress; May 23-26, 2013; Montreal, Quebec, Canada, as part of the Ann Whitmore Collins student research competition.

DOI: 10.2522/ptj.20130104

References

1. Tinetti M, Speechley M, Ginter S. Risk-factors for falls among elderly persons living in the community. N Engl J Med. 1988;319(26):1701-07.

2. SMARTRISK. (2009). The economic burden of injury in Canada. SMARTRISK: Toronto, ON.

3. Rubenstein LZ. Falls in older people: Epidemiology, risk factors and strategies for prevention. Age Ageing. 2006;35:37-41.

4. Sattin R. Falls among older persons - a public-health perspective. Annu Rev Public Health. 1992;13:489-508.

5. Tinetti ME, Kumar C. The patient who falls: "It's always a trade off". JAMA-J Am Med Assoc. 2010;303(3):258-66.

6. Fabre JM, Ellis R, Kosma M, Wood RH. Falls risk factors and a compendium of falls risk screening instruments. J Geriatr Phys Ther. 2010;33(4):184-97.

7. Shumway-Cook A. Motor control: Translating research into clinical practice. 3rd ed. Baltimore, Md.: Lippincott Williams & Wilkins; 2007.

8. Horak FB. Postural orientation and equilibrium: What do we need to know about neural control of balance to prevent falls? Age Ageing. 2006;35(Suppl 2):7-11.

9. Newton RA. Balance and falls among older people. Generations. 2003;27(1):27-31.

10. Berg K, Wooddauphinee S, Williams J. Measuring balance in the elderly - Validation of an instrument. Can J Public Health-Rev Can Sante Publ. 1992;83:S7-S11.

11. Podsiadlo D, Richardson S. The timed up and go - A test of basic functional mobility for frail elderly persons. J Am Geriatr Soc. 1991;39(2):142-8.

12. Muir SW, Berg K, Chesworth B, Speechley M. Use of the Berg balance scale for predicting multiple falls in community-dwelling elderly people: A prospective study. Phys Ther. 2008;88(4):449-59.

13. Shumway-Cook A, Brauer S, Woollacott M. Predicting the probability for falls in community-dwelling older adults using the timed up & go test. Phys Ther. 2000;80(9):896-903.

14. Shumway-Cook A, Baldwin M, Polissar NL, Gruber W. Predicting the probability for falls in community-dwelling older adults. Phys Ther. 1997;77(8):812-9.

15. Horak FB, Wrisley DM, Frank J. The balance evaluation systems test (BESTest) to differentiate balance deficits. Phys Ther. 2009;89(5):484-98.

16. Leddy AL, Crowner BE, Earhart GM. Functional gait assessment and balance evaluation system test: reliability, validity, sensitivity, and specificity for identifying individuals with Parkinson disease who fall. Phys Ther. 2011;91(1):102-13.

17. Leddy AL, Crowner BE, Earhart GM. Utility of the mini-BESTest, BESTest, and BESTest sections for balance assessments in individuals with Parkinson disease. J Neurol Phys Ther. 2011;35(2):90-7.

18. Kurz MJ, Corr B, Stuberg W, Volkman KG, Smith N. Evaluation of lower body positive pressure supported treadmill training for children with cerebral palsy. Pediatr Phys Ther. 2011;23(3):232-9.

19. Jones KD, Horak FB, Winters-Stone K, Irvine JM, Bennett RM. Fibromyalgia is associated with impaired balance and falls. J clin rheumatol. 2009;15(1):16-21.

20. Beauchamp MK, Sibley KM, Lakhani B, Romano J, Mathur S, Goldstein RS, Brooks D. Impairments in systems underlying control of balance in COPD. Chest. 2012;141(6):1496-503.

21. Sibley KM, Straus SE, Inness EL, Salbach NM, Jaglal SB. Balance assessment practices and use of standardized balance measures among Ontario physical therapists. Phys Ther. 2011;91(11):1583-91.

22. Padgett PK, Jacobs JV, Kasser SL. Is the BESTest at its best? A suggested brief version based on interrater reliability, validity, internal consistency, and theoretical construct. Phys Ther. 2012;92(9):1197-207.

23. Franchignoni F, Horak F, Godi M, Nardone A, Giordano A. Using psychometric techniques to improve the balance evaluation systems test: The mini-BESTest. J Rehabil Med. 2010;42(4):323-31.

24. King L, Horak F. On the Mini-BESTest: Scoring and the reporting of total scores. Phys Ther. 2013;93(4):571-5.

25. McNeely ME, Duncan RP, Earhart GM. Medication improves balance and complex gait performance in Parkinson disease. Gait Posture. 2012;36(1):144-8.

26. King LA, Priest KC, Salarian A, Pierce D, Horak FB. Comparing the mini-BESTest with the Berg balance scale to evaluate balance disorders in Parkinson's disease. Parkinsons Dis. 2012;2012:375419.

27. Hill K, Wickerson LM, Woon LJ, Abady AH, Overend TJ, Goldstein RS, Brooks D. The 6-min walk test: responses in healthy Canadians aged 45 to 85 years. Appl Physiol Nutr Me. 2011;36(5):643-9.

28. Steffen TM, Hacker TA, Mollinger L. Age- and gender-related test performance in community-dwelling elderly people: Six-minute walk test, Berg balance scale, timed up & go test, and gait speeds. Phys Ther. 2002;82(2):128-37.

29. Horak F. Available at: http://www.bestest.us/BESTest.pdf, 2008.

30. Isles R, Choy N, Steer M, Nitz J. Normal values of balance tests in women aged 20-80. J Am Geriatr Soc. 2004;52(8):1367-72.

31. Howe TE, Rochester L, Jackson A, Banks PMH, Blair VA. Exercise for improving balance in older people. Cochrane Database Syst Rev. 2007;4:CD004963.

32. Milanovi Z, Pantelli S, Trajkovi N, Spori G, Kosti R, James N. Age-related decrease in physical activity and functional fitness among elderly men and women. Clin Interv Aging. 2013;8:549-56.

33. Fortin M, Bravo G, Hudon C, Vanasse A, Lapointe L. Prevalence of multimorbidity among adults seen in family practice. Ann Fam Med. 2005;3(3):223-8.

34. Springer BA, Marin R, Cyhan T, Roberts H, Gill NW. Normative values for the unipedal stance test with eyes open and closed. J Geriatr Phys Ther. 2007;30(1):8-15.

35. Hofheinz M, Schusterschitz C. Dual task interference in estimating the risk of falls and measuring change: A comparative, psychometric study of four measurements. Clin Rehabil. 2010;24(9):831-42.

Table 1: Description of Subscores and Items of the Balance Evaluation Systems Test[15]

Subscore	**Description**	**Items (Number)**
Biomechanical Constraints	Items in this section evaluate constraints on standing balance including posture, range of motion and strength	Quality of base of support, postural alignment, ankle strength and range of motion, hip strength, ability to sit on floor and stand up. (1-5)
Stability Limits/Verticality	Items in this section evaluate how far the body can move over its base of support and the internal perception of gravitational vertical.	Lateral lean in sitting, verticality, and forward and lateral reach. (6-8)
Anticipatory Postural Adjustments	Items in this section evaluate active movement of the centre of mass in anticipation of positional changes.	Sit to stand, rise to toes, single leg stance, stair tap, and standing arm raise. (9-13)
Postural Responses	Items in this section evaluate in-place and compensatory stepping responses to external perturbations.	In place resistance to perturbation and forward, backward and lateral response to "push and release". (14-18)
Sensory Orientation	Items in this section evaluate increases in postural sway under different sensory conditions.	Standing on flat ground and foam with eyes open or closed and standing on ramp with eyes closed. (19-20)
Stability in Gait	Items in this section evaluate stability while walking under conditions when balance is challenged.	Usual gait speed, change in speed, walking with head turns, quick turn and stop, stepping over obstacle, Timed Up and Go (TUG), TUG with cognitive dual-task. (21-27)

Table 2: Participant Characteristics

		Age Cohort (years) 50-59			**60-69**			**70-79**			**80-89**		
	Gender	n	Mean(SD)	Min, Max	n	Mean(SD)	Min, Max	n	Mean(SD)	Min, Max	n	Mean(SD)	Min, Max
Age	Total	20	55.5(3.1)	50, 59	20	63.5(2.9)	60, 69	20	74.0(0.5)	70, 79	19	82.5(0.5)	80, 87
	Male	10	54.6(3.0)	50, 58	10	64.2(3.1)	60, 69	10	73.4(2.0)	70, 77	9	82.3(2.6)	80, 87
	Female	10	56.4(3.1)	50, 59	10	62.8(2.8)	60, 67	10	74.5(2.3)	71, 79	10	82.6(2.2)	80, 87
Height	Total	20	1.7(0.1)	1.5, 1.9	20	1.7(0.0)	1.5, 1.8	20	1.7(0.0)	1.6, 1.9	19	1.6(0.0)	1.5, 1.8
	Male	10	1.8(0.1)	1.7, 1.9	10	1.8(0.0)	1.7, 1.8	10	1.7(0.1)	1.6. 1.9	9	1.7(0.0)	1.7, 1.8
	Female	10	1.6(0.1)	1.5, 1.7	10	1.7(0.1)	1.5, 1.8	10	1.6(0.0)	1.6, 1.7	10	1.5(0.1)	1.5, 1.7
Weight	Total	20	72.5(19.1)	52.3, 116.0	20	75.8(3.0)	52.2, 100.2	20	70.3(2.0)	50.5, 83.0	19	67.1(2.6)	50.5, 83.0
	Male	10	81.6(15.4)	59.1, 105.2	10	81.4(9.7)	64.0, 100.2	10	77.6(3.6)	72.0, 83.0	9	75.1(8.0)	61.0, 83.0
	Female	10	63.5(18.8)	52.3, 116.0	10	70.2(14.7)	52.2, 97.5	10	63.1(6.3)	50.5, 72.6	10	59.9(8.9)	50.5, 79.5
BMI	Total	20	25.2(4.9)	20.1, 31.8	20	26.1(1.1)	19.1, 35.8	20	25.0(0.6)	18.6, 30.1	19	25.6(0.8)	20.2, 32.3
	Male	10	26.0(3.9)	20.1, 31.8	10	26.5(3.9)	21.4, 35.1	10	25.8(2.7)	20.7, 30.1	9	26.1(2.6)	21.9, 29.0
	Female	10	24.4(5.8)	20.1, 30.7	10	25.8(5.8)	19.1, 35.8	10	24.2(2.3)	18.6, 26.7	10	25.2(4.0)	20.2, 32.3

SD = Standard Deviation; BMI = Body Mass Index

Table 3: BESTest, mini-BESTest and briefBESTest Scores for Canadians Aged 50-89

	Age Cohort (years)												**Kruskal-Wallis**		
	50-59			**60-69**			**70-79**			**80-89**			**Chi-square**	**df**	***p*-value**
Item	n	Mean(SD)	95% CI	n	Mean(SD)	95% CI	n	Mean(SD)	95% CI	n	Mean(SD)	95% CI			
BESTest Total (%)	20	95.7(2.9)	94.4-97.1	20	91.4(3.4)	89.8-93.0	20	85.4(6.0)	82.5-88.2	19	79.4(10.6)	74.3-84.5	47.990	3	<0.001
Biomechanical Constraints (%)*	20	96.3(9.0)	92.1-100.6	20	89.0(9.5)	84.6-93.4	20	83.7(10.5)	78.8-88.6	19	78.6(13.4)	72.1-85.1	28.843	3	<0.001
Stability Limits/ Verticality (%)*	20	94.8(4.3)	92.7-96.8	20	92.1(6.6)	89.1-95.2	20	87.1(8.0)	83.4-90.9	19	85.2(9.1)	80.8-89.6	17.463	3	0.001
Transitions-Anticipatory (%)*	20	97.8(5.2)	95.3-100.2	20	94.4(6.7)	91.3-97.6	20	85.6(12.3)	79.8-91.3	19	75.1(18.2)	66.4-83.9	28.401	3	<0.001
Transitions-Reactive (%)*	20	96.9(4.6)	94.8-99.1	20	88.3(9.9)	83.7-92.9	20	85.5(7.9)	81.8-89.3	19	76.9(17.3)	68.5-85.2	29.460	3	<0.001
Sensory Orientation (%)*	20	98.3(3.0)	96.9-99.7	20	96.7(5.1)	94.3-99.0	20	94.7(10.1)	90.0-99.4	19	88.8(14.1)	82.0-95.5	11.782	3	0.008
Stability In Gait (%)*	20	92.6(5.0)	90.3-94.9	20	90.0(6.5)	86.9-93.1	20	77.8(12.3)	72.1-83.6	19	73.1(13.2)	66.8-79.5	36.571	3	<0.001
Mini-BESTest (/28)	19	26.3(1.1)	25.7-26.8	18	24.7(2.2)	23.6-25.8	20	21.0(3.1)	19.5-22.4	19	19.6(4.2)	17.6-21.6	41.662	3	**<0.001**
BriefBESTest (/24)	20	22.7(1.7)	21.9-23.5	20	20.5(2.2)	19.5-21.6	20	18.8(3.3)	17.3-20.4	19	15.0(4.7)	12.8-17.3	37.608	3	**<0.001**

Biomechanical Constraints (/3)†	20	2.9(0.5)	2.6-3.1	20	2.1(1.2)	1.5-2.6	20	2.2(1.0)	1.8-2.7	19	1.8(1.0)	1.4-2.3	14.392	3	0.002
Stability Limits/ Verticality (/3)†	20	2.7(0.5)	2.5-2.9	20	2.5(0.5)	2.3-2.7	20	2.4(0.5)	2.1-2.6	19	2.0(0.5)	1.8-2.2	16.710	3	0.001
Transitions-Anticipatory (/6)†	20	5.7(0.9)	5.3-6.1	20	5.6(0.8)	5.2-5.9	20	4.0(2.0)	3.0-4.9	19	2.6(2.1)	1.6-3.7	29.417	3	<0.001
Transitions-Reactive (/6)†	20	5.7(0.7)	5.3-6.0	20	4.9(1.2)	4.3-5.4	20	4.8(0.7)	4.4-5.1	19	3.8(2.0)	2.8-4.8	17.413	3	0.001
Sensory Orientation (/3)†	20	2.8(0.4)	2.6-3.0	20	2.6(0.6)	2.3-2.9	20	2.7(0.6)	2.4-2.9	19	2.1(0.8)	1.7-2.5	10.566	3	0.014
Stability in Gait (/3)†	20	3.0(0.0)	3.0-3.0	20	3.0(0.0)	3.0-3.0	20	2.9(0.3)	2.8-3.0	19	2.6(0.5)	2.4-2.9	17.152	3	0.001

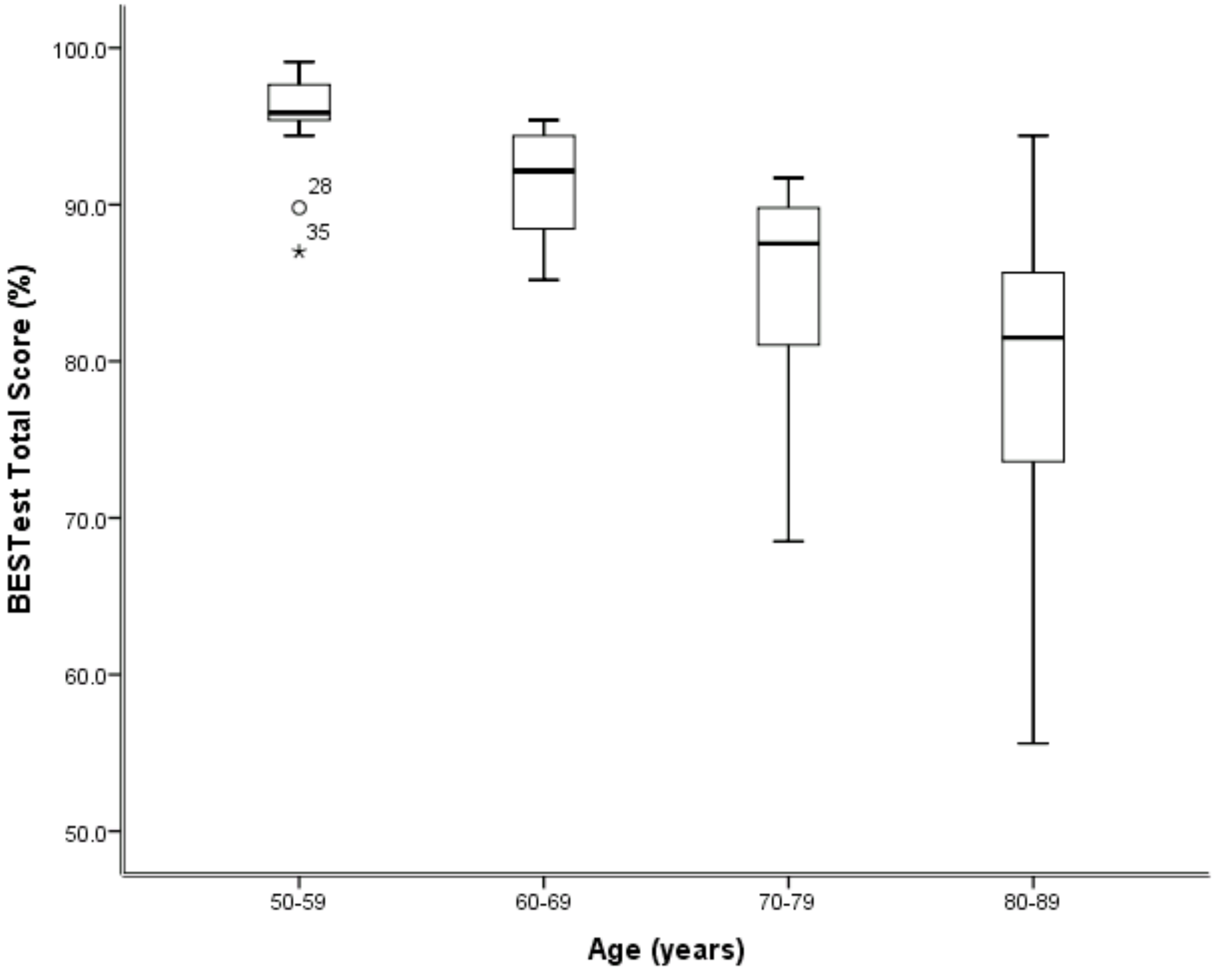
*BESTest subscore; †briefBESTest subscore; SD = Standard Deviation; 95% CI = 95% Confidence Interval; df = degrees of freedom.

Figure 1. This boxplot compares the total BESTest scores for the four age cohorts ($p < 0.001$, Kruskal-Wallis test). Minimum and maximum values, the upper (Q3) and lower (Q1) quartiles and the median are depicted. The median is identified by a line inside the box. The length of the box represents the interquartile range. Values more than three IQRs from either end of the box are labeled as extremes and are denoted by an asterisk (*). Values more than 1.5 IQRs but less than three IQRs from either end of the box are labeled as outliers (o).

Figure 2. This boxplot compares the mini-BESTest scores for 4 age cohorts ($p < 0.001$, Kruskal-Wallis test). Minimum and maximum values, the upper (Q3) and lower (Q1) quartiles and the median are depicted. The median is identified by a line inside the box. The length of the box represents the interquartile range. Values more than three IQRs from either end of the box are labeled as extremes and are denoted by an asterisk (*). Values more than 1.5 IQRs but less than three IQRs from either end of the box are labeled as outliers (o).

Figure 3. This boxplot compares the total briefBESTest scores for 4 age cohorts ($p < 0.001$, Kruskal-Wallis test). Minimum and maximum values, the upper (Q3) and lower (Q1) quartiles and the median are depicted. The median is identified by a line inside the box. The length of the box represents the interquartile range. Values more than three IQRs from either end of the box are labeled as extremes and are denoted by an asterisk (*). Values more than 1.5 IQRs but less than three IQRs from either end of the box are labeled as outliers (o).

Figure 1



BESTest Total Score (%)
100.0
90.0
80.0
70.0
60.0
50.0
28
35
50-59
60-69
70-79
80-89
Age (years)

Figure 2

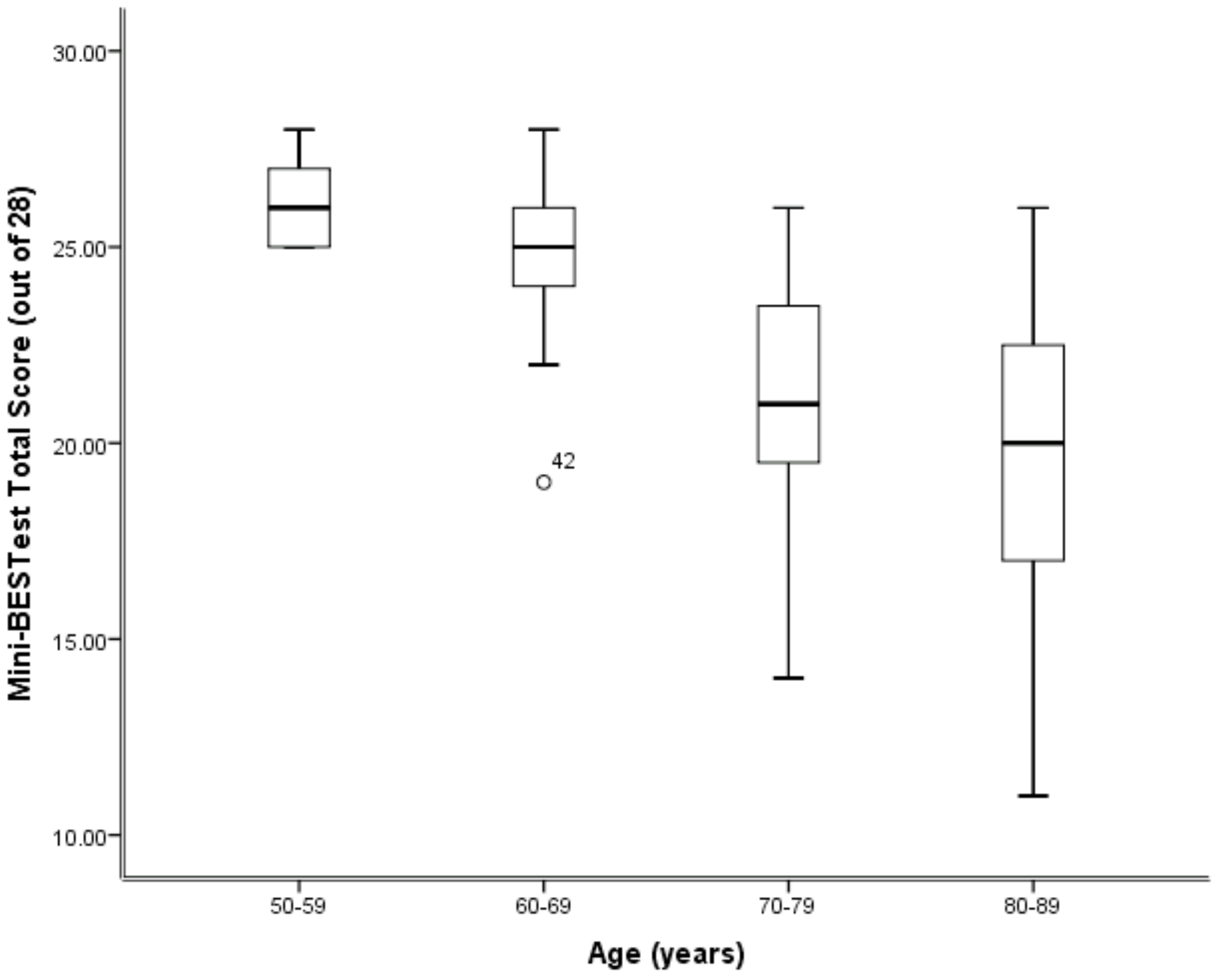
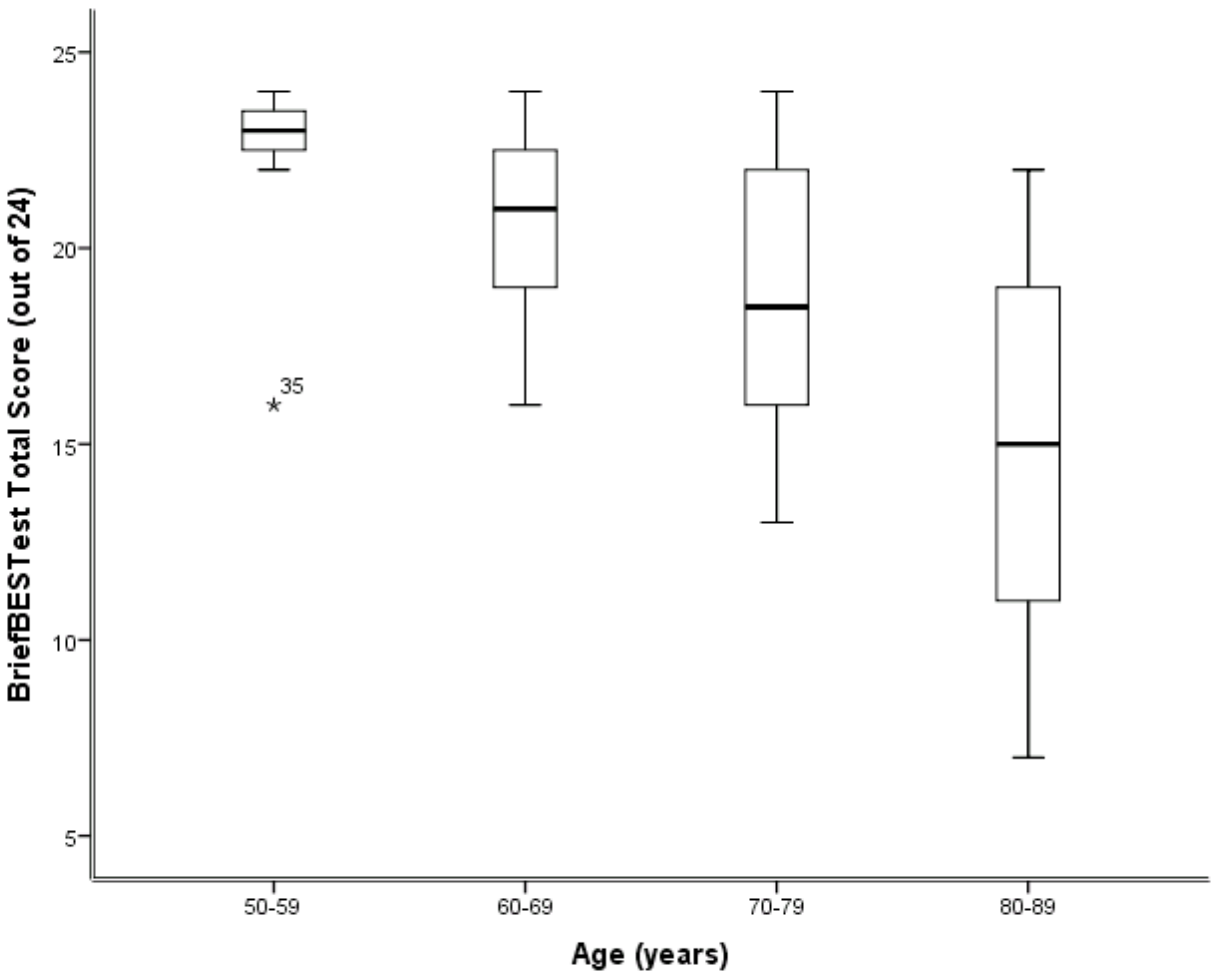

30.00
25.00
20.00
15.00
10.00
Mini-BESTest Total Score (out of 28)
42
50-59
60-69
70-79
80-89
Age (years)

Figure 3


BriefBESTest Total Score (out of 24)
25
20
15
10
5
35
50-59
60-69
70-79
80-89
Age (years)

Physical Therapy
Journal of the American Physical Therapy Association and de Fysiotherapeut
Royal Dutch Society for Physical Therapy

PTJ Online First

Increasing the Clinical Utility of the BESTest, Mini-BESTest, and BriefBESTest: Normative Values in Canadian Adults Who Are Healthy and Aged 50 Years and Over

Sachi O'Hoski, Bonnie Winship, Lauren Herridge, Taimoor Agha, Dina Brooks, Marla K. Beauchamp and Kathryn M. Sibley

PHYS THER. Published online October 3, 2013
doi: 10.2522/ptj.20130104