NON-COMUNICABLE DISEASES

# Balance measures of mini and brief balance evaluation system tests for Iranian population

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Keywords

Balance • Mini-BESTest • Brief-BESTest • Normative values

Summary

**Introduction**. *Falling is a serious problem for all ages. There are several tests to assess balance. Mini-BESTest and brief-BESTest are balance tests for which there are no normative values for Iranian people. We aimed to provide the normative values of mini-BESTest and brief-BESTest among healthy Iranian adults.*
**Methods**. *A cross-sectional study was designed. Three hundred healthy adults (150 males and 150 females) in six age groups (18-29, 30-39, 40-49, 50-59, 60-69, +70 years) completed the tests using Persian mini-BESTest and brief-BESTest. Normative values were calculated for age groups.*
**Results**. *Normative values of mini-BESTest and brief- BESTest decreased significantly with age (from 27 to 21.9 for mini-BESTest and from 22.9 to 15.4 for brief BESTest). There were no significant differences between genders except for females in 30-39 and 40-49 years age groups which scored better on brief-BESTest and mini-BESTest, respectively. Males had significantly scored better in brief- BESTest in 60-69 and ≥ 70 age groups.*
**Conclusions**. *The normative values of the mini-BESTest and brief-BESTest provided for healthy Iranian adults can help clinicians when assessing subjects with balance dysfunction.*

## Introduction

Balance is the ability of the individual to control their posture. The balance system is essential for daily activities, maintaining posture, and moving in different conditions [1]. Balance is a complex phenomenon resulting from the interaction between skeletal, neuromuscular, and sensory systems [2]. Problems in sensory, cognitive, or motor systems can cause balance deficits [1]. Balance deficits reduce physical function, leading to falls, fall-related injuries, and activity restriction [3].

Falling is a serious problem for all ages. In the United States, about 42% of medically consulted injuries were due to fall in 2010 [4], and one-third of fall injuries occurred in various age groups [5]. Orthopedic injuries like fractures, dislocations, sprains are the most common fall-related injuries [5, 6]. The mortality rate increases with age, and falling directly contributes to about 1800 deaths [7].

The annual cost of fall-related injuries is about 471$ per person in the United States and increases with age from 238$ per person for the 18-24 years age group to 1186$ for the +75 years age group [5]. Hence, balance assessment is important to detect dysfunctions and determine the treatments' effectiveness [3].

Timed Up & Go (TUG) test and Berg Balance Scale (BBS) are the most commonly used tools to assess balance. The TUG test is a functional balance test that is sensitive and specific in identifying community-dwelling adults at risk of fall [8] but cannot discriminate between fallers and non-fallers in high functioning elderly [9]. The BBS has excellent inter and intra-rater reliability [10] but suffers from floor and ceiling effects [11].

Balance Evaluation System Test (BESTest) developed in 2009 consists of 36 items and six sections, including biomechanical constraints, stability limits/vertically, anticipatory postural adjustment, postural response, sensory orientation, and stability in gait [12]. Hence, BESTest can identify the system responsible for the probable balance deficit, which can help direct the treatment specifically on the patient's problem [12]. A recent study showed that the BESTest scores significantly differ between fallers and non-fallers [13]. BESTest also has excellent reliability [1, 14-17] and good to excellent validity in different populations [12-15]. However, the BESTest takes about 30 minutes to perform in the clinical setting. Therefore, a shorter version of BESTest appeared in 2010 called the mini-BESTest [18].

Mini-BESTest assesses the dynamic balance and consists of 14 items of BESTest, which are more practical and psychometrically useful [18]; however, its total score has a good to excellent correlation with BESTest total score and predicts 58.8% to 68% of the variance in dynamic balance [18, 19]. The Mini-BESTest takes about 10-15 minutes to perform, increasing its feasibility [18]. The Mini-BESTest has higher sensitivity

https://doi.org/10.15167/2421-4248/jpmh2024.65.1.3051

and specificity than BESTest in predicting people with a history of falls [17]. It also has excellent test-retest and inter-rater reliability [14, 19, 21, 22], good to excellent correlation with the BBS in various populations [21-24], and excellent responsiveness in patients with different balance disorders [21, 25].

Although mini-BESTest could be administered in a shorter duration, there was a need for a shorter version of the test for use in the clinics. In addition, the mini-BESTest only assesses the dynamic balance, and biomechanical constraints and limits of stability/vertically systems are not evaluated in mini-BESTest, which is against the theoretical basis of BESTest. In order to retain the theoretical basis of the BESTest, the brief-BESTest developed, which is another shorter version of BESTest.

Brief-BESTest contains six items that are representative of each section of BESTest [26]. Brief-BESTest takes less time to perform than mini-BESTest and has excellent inter-rater reliability, even more reliable than mini-BESTest and BESTest, and excellent test-retest reliability [27]. Brief-BESTest has comparable sensitivity and specificity to mini-BESTest and BESTest in discriminating patients with a fall history [27]; however, it has a limited sensitivity to change [28]. Brief-BESTest can discriminate fallers and non-fallers in the elderly population; however, this ability diminishes in younger populations [29].

Normative values of mini-BEST and brief-BESTest can be used as reference range to help clinicians and researchers to interpret tests results in people with balance dysfunction. There are normative values of BESTest, mini-BESTest, and brief- BESTest reported for healthy Canadian adults aged ≥ 50 years old [30]; however, there is no normative data for other age groups. Moreover, in the previous study, a small sample size of 20 people in each age group was included [30]. The lack of a larger study with a normal range for all age groups makes it difficult to interpret the tests' results restricting the clinical utility of mini-BEST and brief-BESTest. Therefore, the present study aimed to determine the normative values of mini-BESTest and brief-BESTest in healthy Iranian adults across age groups and genders.

## Materials and methods

### Design

A cross-sectional study was designed. Data were collected in ten months from August 2015 to June 2016 in Tehran. The ethics committee of the Tehran University of medical sciences approved the study protocol (IR. TUMS.REC.1394.1512).

*Subjects*

Healthy community-dwelling adults who were 18 years of age and older were recruited from public places such as mosques, universities, factories, parks, *etc.* The purpose of the study was described to participants before taking part in the study, and oral consent was obtained from all participants. A sample size of at least 20 people in each age group was reported in a previous study [30], then we targeted a sample size of 300 subjects in six age groups (18-29, 30-39, 40-49, 50-59, 60-69 and ≥ 70) with 25 men and 25 women in each age group.

The inclusion criteria were: 1) age ≥ 18 years; 2) living independently in the community; 3) ability to speak and read Persian; 4) ability to follow commands; 5) ability to walk 6 meters without any help; 6) giving consent; 7) no history of faint, vertigo or dizziness or current use of medications which can cause dizziness; 8) no past or current history of any medical condition which can affect the balance including neurological diseases such as Parkinson's disease or multiple sclerosis, musculoskeletal disorders such as arthritis, and vestibular disorders.

*Instruments*

Mini-BESTest consists of 14 items scored from 0 to 2. The total score is the sum of all item scores from 0 to 28 [18, 31]. Mini-BESTest is translated to Persian, and its Persian version is reliable and valid for evaluating balance among Iranian people [32, 33].

Brief- BESTest has six sections, each with one item. The items 'Stand on one leg' and "Compensatory step lateral' are scored bilaterally. Each item is being scored on a scale from 0 to 3. All eight items' scores are summed to obtain the total score ranging from 0 to 24 [26] (Tab. I). Persian version of Brief-BESTest is also a reliable and valid tool for balance evaluation in Iranian people [33, 34]. For both Mini-BESTest (www.bestest.us) and Brief-BESTest, we used the Persian versions for scoring and instructing the participants [33].

*Procedure*

Six raters participated and collected the data that five of them were medical students, and one was a physiotherapist. All raters underwent training using the BESTest training DVD provided by Professor Fay B. Horak under the supervision of SN, an expert, experienced physiotherapist, and Professor. Under the supervision of SN, raters practiced the tests procedure and scoring until they reached an agreement on tests performance and scoring.

We selected several public places such as universities and mosques in Tehran and recruited the participants from these places. In order to facilitate the participation in the study, we prepared a room in each of these places, which was separate from the working environment and crowded environments, and performed the tests in these rooms. After obtaining oral consent, participants' demographic information such as age, gender, weight, height, educational level, and the job was recorded. In order to test the participants, one rater read the Persian instruction of each item for the subject and asked the subject to perform the items. Then, the rater scored each item immediately after the subject's performance. The items 'Hip/trunk lateral strength' and 'Functional reach forward' from brief-BESTest were first performed by the subjects, and then, the mini-BESTest items were tested.

**Tab. I.** Sections and related items in Mini-BESTest and Brief-BESTest.

| Test | Section | Item |
|---|---|---|
| Mini-BESTest (scores range from 0 to 28) | Anticipatory (scores range from 0 to 6) | Sit to Stand* |
| | | Rise to toes* |
| | | Stand on one leg* |
| | Reactive postural control (scores range from 0 to 6) | Compensatory stepping correction- Forward* |
| | | Compensatory stepping correction- Backward* |
| | | Compensatory stepping correction- lateral* |
| | Sensory orientation (scores range from 0 to 6) | Stance (Feet together); eyes open, firm surface* |
| | | Stance (Feet together); eyes closed, foam surface* |
| | | Inline- eyes closed* |
| | Dynamic gait (scores range from 0 to 10) | Change in gait speed* |
| | | Walk with head turns- horizontal* |
| | | Walk with pivot turns* |
| | | Step over obstacles* |
| | | Timed Up & Go with dual task* |
| Brief BESTest (scores range from 0 to 24) | Biomechanical constraints (scores range from 0 to 3) | Hip/trunk lateral strength** |
| | Stability limits (scores range from 0 to 3) | Functional reach forward** |
| | Transitions–anticipatory postural adjustment (scores range from 0 to 6) | Stand on one leg-left and right*** |
| | Reactive postural response (scores range from 0 to 6) | Compensatory stepping-lateral, left and right*** |
| | Sensory orientation (scores range from 0 to 3) | Stance with eyes closed, on foam surface** |
| | Stability in gait (scores range from 0 to 3) | Timed "Up & Go" test** |

* Scores range from 0 to 2. ** Scores range from 0 to 3. *** These items are scored bilaterally, and scores range from 0 to 6.
Note: Total scores of Mini-BESTest and Brief-BESTest, and their sections scores are calculated by the sum of all related items' scores.

*Data Analysis*

Descriptive statistics of mean and standard deviation (SD) were calculated for continuous variables. The Kolmogorov-Smirnov test was used to assess whether the distribution of mini-BEST and brief-BESTest total scores and their subscales' scores are normal. Since these variables were not distributed normally ($p < 0.05$), we used the Kruskal-Wallis test to determine the differences between age groups, and median and interquartile range (IQR) were calculated for these variables. If there was a significant difference between age groups, posthoc analysis was performed to assess the differences between groups. The Mann-Whitney U test was used to determine whether there is a significant difference in mini-BESTest and brief-BESTest total scores and their subscales' scores between genders. SPSS software (version 16 for windows, SPSS inc, Chicago, Illinois) was used for all analyses. We considered $p \leq 0.05$ as statistically significant.

## Results

Three hundred healthy adults with a mean age of 49.0 years (SD = 17.8) participated in this study. For each age group, 50 subjects (25 males and 25 females) were assessed. The demographic data of each age group are shown in Table II.

### Mini-BESTest

Participants' scores decreased significantly across all mini-BESTest total scores and all of its subscales' scores ($p < 0.05$). Adults who were 70 years or older had significantly lower scores than other age groups across all subscales and the mini-BESTest total score ($p < 0.05$), except in the sensory orientation subscale, in which there was no significant difference between ≥ 70 years age group and other age groups. Also, there was no significant difference between ≥ 70 years and 60-69 years age group in the dynamic gait subscale ($p = 1$). Figure 1 shows the age-related decline in the mini-BESTest score.

Males had significantly higher anticipatory subscale scores than females in the 50-60 and 60-69 age groups ($p < 0.05$). Also, 60-69 years participants had significantly lower scores in this subscales than those who were 18-39 years ($p < 0.05$). Females had significantly higher scores than males in reactive postural control subscales, except in 50-59 years ($p = 0.494$) and ≥ 70 years ($p = 0.093$) groups. Also, adults who were 18-29 years had significantly higher scores than those who were 60-69 years ($p = 0.026$). In the sensory orientation, males had significantly higher scores than females in the 60-69 years age group ($p = 0.039$). In contrast, in the dynamic gait subscale females had significantly higher scores than males in the 40-49 years group ($p = 0.005$). In the dynamic gait subscale, adults who were 60-69 years had significantly lower scores than younger adults ($p < 0.05$). Normative values of mini-BESTest were not significantly different between males

Tab. II. Demographic data by age.

| | Age groups (year) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 18-29 (n = 50) | | 30-39 (n = 50) | | 40-49 (n = 50) | | 50-59 (n = 50) | | 60-69 (n = 50) | | ≥ 70 (n = 50) | | Total (n = 300) | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Age (year) | 22.3 | 2.2 | 33.6 | 2.7 | 45.3 | 2.7 | 54.4 | 3.0 | 64.1 | 2.4 | 74.3 | 3.9 | 49.0 | 17.8 |
| Weight (kg) | 66.9 | 13.6 | 71.1 | 14.8 | 71.1 | 12.4 | 72.4 | 12.8 | 73.0 | 11.1 | 68.9 | 11.7 | 70.5 | 12.8 |
| Height (cm) | 169.9 | 9.7 | 168.3 | 8.4 | 166.9 | 8.7 | 166.4 | 9.7 | 165.3 | 8.3 | 166.0 | 9.0 | 167.1 | 9.0 |
| Body mass index ($kg/m^2$) | 23 | 3.1 | 25.0 | 4.6 | 25.4 | 3.7 | 26.1 | 3.6 | 26.7 | 3.7 | 24.9 | 3.6 | 25.2 | 3.9 |

SD: standard deviation.

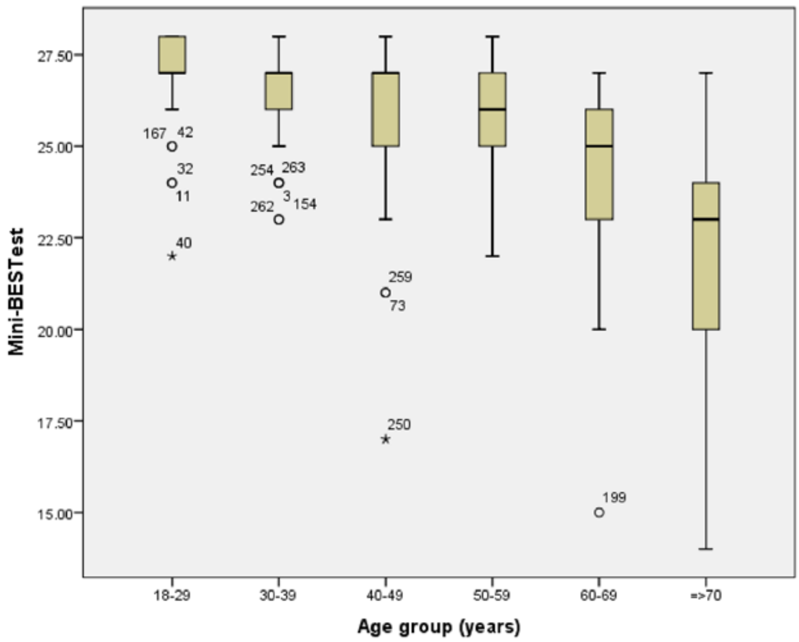
and females across age groups except for the 40-49 age group in which females had performed better (p = 0.022). Also, adults who were 60-69 years had significantly lower scores than those who were 18-49 years p < 0.05). Also, those who were 18-29 years had significantly higher scores than those who were 50-59 years (p = 0.001). There was no other significant difference between age groups and genders regarding the mini-BEST total score and its subscales scores (p > 0.05) (Tab. III).

Mini-BESTest total score and all its subscale scores based on participants' occupations and educational levels are shown in Table IV. There were significant differences between all educational groups in the anticipatory subscale, with people with higher educational levels had significantly higher scores. Also, people with a degree higher than a diploma had higher scores in mini-BESTest, reactive postural control, and dynamic gait subscale than people with lower educational levels (p < 0.05). Also, people with an educational degree of lower than diploma had lower scores in the sensory orientation subscale than people with higher educational degrees (p < 0.05). There were also significant differences between occupations across mini-BESTest total score and all its subscales' scores (p < 0.05).

### Brief-BESTest

Brief-BESTest total scores and all its subscales decreased significantly with age (p < 0.05). Participants who were 70 years or older had significantly lower scores than other age groups in transitions–anticipatory postural adjustment, reactive postural response, and stability in gait subscales (p < 0.05). These participants also had lower scores than participants who were younger than 60 years in biomechanical constraints, stability limits subscales, and the brief-BESTest total score (p < 0.05), with the only exception, was in the stability limits subscale, in which there was no significant difference between adults who were 70 years or older and participants who were 40 to 49 years (p = 0.094). Figure 2 shows the age-related decline in the brief-BESTest score.

Fig. 1. Mini-BESTest total scores across age groups. Middle thick line, median; bottom box, first quartile; upper box, third quartile; lower whisker, minimum (excluding outliers and extremes); upper whisker, maximum (excluding outliers and extremes); circle, outlier; star, extreme value. Numbers beside the stars and circles indicate the code of the subject.



**Tab. III.** Normative values of balance Mini-BESTest and Brief-BESTest in healthy Iranian subjects (n = 300).

| Tests | Total | 18-29 years | | | | 30-39 years | | | | 40-49 years | | | | 50-59 years | | | | 60-69 years | | | | ≥ 70 years | | | | p-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total (N = 50) | Male (N = 25) | Female (N = 25) | p-value | Total (N = 50) | Male (N = 25) | Female (N = 25) | p-value | Total (N = 50) | Male (N = 25) | Female (N = 25) | p-value | Total (N = 50) | Male (N = 25) | Female (N = 25) | p-value | Total (N = 50) | Male (N = 25) | Female (N = 25) | p-value | Total (N = 50) | Male (N = 25) | Female (N = 25) | p-value | |
| Anticipatory | 6 (1) | 6 (0) | 6 (0) | 6 (0) | 0.556 | 6 (0) | 6 (1) | 6 (0) | 0.151 | 6 (1) | 6 (1) | 6 (1) | 0.921 | 6 (1) | 6 (0) | 6 (1) | 0.009 | 5 (1) | 6 (1) | 5 (1.5) | 0.005 | 4 (1.25) | 5 (1.5) | 4 (1.5) | 0.285 | < 0.001 |
| Reactive postural control | 6 (1) | 6 (0) | 6 (1) | 6 (0) | 0.012 | 6 (0) | 6 (1) | 6 (0) | < 0.001 | 6 (1) | 6 (1.5) | 6 (0) | 0.018 | 6 (1) | 6 (1) | 6 (1) | 0.494 | 5 (2) | 5 (2) | 6 (1) | 0.042 | 4 (2.25) | 5 (1.5) | 3 (4) | 0.093 | < 0.001 |
| Sensory orientation | 6 (0) | 6 (0) | 6 (0) | 6 (0) | 0.153 | 6 (0) | 6 (0) | 6 (0) | 1 | 6 (0) | 6 (0) | 6 (0) | 0.317 | 6 (0) | 6 (0) | 6 (0) | 1 | 6 (0) | 6 (0) | 6 (1) | 0.039 | 6 (0) | 6 (0) | 6 (0) | 0.174 | 0.042 |
| Dynamic gait | 9 (1) | 10(1) | 10 (1) | 10 (1) | 0.885 | 9 (1) | 10 (1) | 9 (0.5) | 0.082 | 9(2) | 9 (1) | 9 (1) | 0.005 | 9 (1) | 9 (1) | 9 (0.5) | 0.814 | 8 (1) | 8 (0.5) | 9 (1.5) | 0.336 | 8 (1) | 8 (1) | 8 (2) | 0.297 | < 0.001 |
| Mini-BESTest | 26 (3) | 27 (1) | 27 (2) | 27 (1) | 0.392 | 27 (1.25) | 27 (1.5) | 27 (2) | 0.252 | 27 (2) | 26 (3) | 27 (1) | 0.022 | 26 (2) | 26 (1.5) | 26 (2) | 0.29 | 25 (3) | 25 (3) | 25 (3) | 0.882 | 23 (4) | 23 (3) | 22 (5) | 0.213 | < 0.001 |
| Biomechanical constraints | 3 (1) | 3 (1) | 3 (1) | 3 (0) | 0.067 | 3 (1) | 2 (1) | 3 (0) | < 0.001 | 3 (1) | 3 (1) | 3 (1) | 0.937 | 3 (1) | 3 (1) | 3 (1.5) | 0.536 | 2 (2) | 2 (2) | 2 (3) | 0.565 | 1 (2) | 2 (3) | 1 (1.5) | 0.636 | < 0.001 |
| Stability limits | 2 (1) | 3 (1) | 3 (0.5) | 3 (1) | 0.533 | 2 (1) | 2 (1) | 2 (1) | 0.777 | 2 (1) | 2 (1) | 2 (1) | 0.319 | 3 (1) | 3 (1) | 2 (1) | 0.112 | 2 (0) | 2 (1) | 2 (0.5) | 0.005 | 2 (0) | 2 (0.5) | 2 (1) | 0.003 | < 0.001 |
| Transitions-anticipatory postural adjustment | 6 (2) | 6 (0) | 6 (0.5) | 6 (0) | 0.01 | 6 (0) | 6 (0) | 6 (0) | 0.76 | 6 (2) | 6 (2) | 6 (1.5) | 0.811 | 6 (2) | 6 (1) | 5 (3) | 0.031 | 4 (3.25) | 5 (2) | 4 (4) | 0.024 | 2.5 (3) | 4 (2.5) | 2 (3) | 0.005 | < 0.001 |
| Reactive postural response | 6 (1) | 6 (0) | 6 (0) | 6 (0) | 0.293 | 6 (0) | 6 (1) | 6 (0) | 0.005 | 6 (0) | 6 (1) | 6 (0) | 0.089 | 6 (0) | 6 (0.5) | 6 (0) | 0.989 | 6 (1) | 6 (1) | 6 (0.5) | 0.327 | 5 (4) | 5 (2) | 2 (4) | 0.006 | < 0.001 |
| Sensory orientation | 3 (0) | 3 (0) | 3 (0) | 3 (0) | 0.153 | 3 (0) | 3 (0) | 3 (0) | 1 | 3 (0) | 3 (0) | 3 (0) | 0.556 | 3 (0) | 3 (0) | 3 (0) | 0.317 | 3 (0) | 3 (0) | 3 (0) | 0.336 | 3 (0) | 3 (0) | 3 (0.5) | 0.053 | 0.022 |
| Stability in gait | 3 (0) | 3 (0) | 3 (0) | 3 (0) | 1 | 3 (0) | 3 (0) | 3 (0) | 0.153 | 3 (0) | 3 (0) | 3 (0) | 0.317 | 3 (0) | 3 (0) | 3 (0) | 0.077 | 3 (0) | 3 (0) | 3 (0.5) | 0.044 | 3 (1) | 3 (0.5) | 2 (1) | 0.004 | < 0.001 |
| Brief-BESTest | 22 (4) | 23 (1) | 23 (3.5) | 24 (1) | 0.245 | 23 (1.5) | 22 (2) | 23 (1) | 0.005 | 22 (2) | 22 (3.5) | 22 (2) | 0.89 | 22 (4) | 23 (2.5) | 21 (7) | 0.108 | 20 (4.25) | 20 (3.5) | 18 (6.5) | 0.037 | 15 (7) | 18 (4.5) | 13 (4) | < 0.001 | < 0.001 |

Values are reported as median (IQR)

Tab. IV. Normative values of balance Mini-BESTest and Brief-BESTest based on occupation and educational level.

| | Educational level | | | | Occupation | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Lower than diploma | Diploma | Higher than diploma | p-value | Student | Clerk | Worker | Housewife | Other | p-value |
| Anticipatory | 5 (2) | 6 (1) | 6 (0) | < 0.001 | 6 (0) | 6 (0) | 6 (1) | 5 (2) | 6 (1) | < 0.001 |
| Reactive postural control | 6 (2) | 6 (2) | 6 (1) | 0.008 | 6 (0) | 6 (1) | 6 (1) | 6 (2) | 5 (2) | < 0.001 |
| Sensory orientation | 6 (0) | 6 (0) | 6 (0) | < 0.001 | 6 (0) | 6 (0) | 6 (0) | 6 (0) | 6 (0) | 0.023 |
| Dynamic gait | 8 (1) | 9 (1) | 9 (1) | < 0.001 | 10 (1) | 9 (1) | 9 (1.5) | 9 (1) | 8 (1) | < 0.001 |
| Mini-BESTest | 24 (3.75) | 26 (4) | 27 (2) | < 0.001 | 28 (1) | 27 (1) | 26 (2.5) | 25 (3) | 25 (4) | < 0.001 |
| Biomechanical constraints | 2 (1) | 2 (1) | 3 (1) | < 0.001 | 3 (0) | 3 (1) | 2 (1) | 2 (2) | 3 (1) | < 0.001 |
| Stability limits | 2 (0) | 2 (1) | 3 (1) | < 0.001 | 3 (1) | 2 (1) | 2 (1) | 2 (0) | 2 (1) | < 0.001 |
| Transitions–anticipatory postural adjustment | 4 (4) | 6 (2) | 6 (1) | < 0.001 | 6 (0) | 6 (0.25) | 6 (2) | 4 (4) | 6 (2) | < 0.001 |
| Reactive postural response | 6 (2) | 6 (1) | 6 (0) | < 0.001 | 6 (0) | 6 (0) | 6 (0) | 6 (2) | 6 (1) | 0.001 |
| Sensory orientation | 3 (0) | 3 (0) | 3 (0) | 0.006 | 3 (0) | 3 (0) | 3 (0) | 3 (0) | 3 (0) | 0.088 |
| Stability in gait | 3 (1) | 3 (0) | 3 (0) | < 0.001 | 3 (0) | 3 (0) | 3 (0) | 3 (1) | 3 (0) | < 0.001 |
| Brief-BESTest | 18 (6) | 22 (4.5) | 23 (3) | < 0.001 | 24 (1) | 23 (2) | 22 (2.5) | 17 (7.5) | 21 (4) | < 0.001 |

Values are reported as median (IQR)

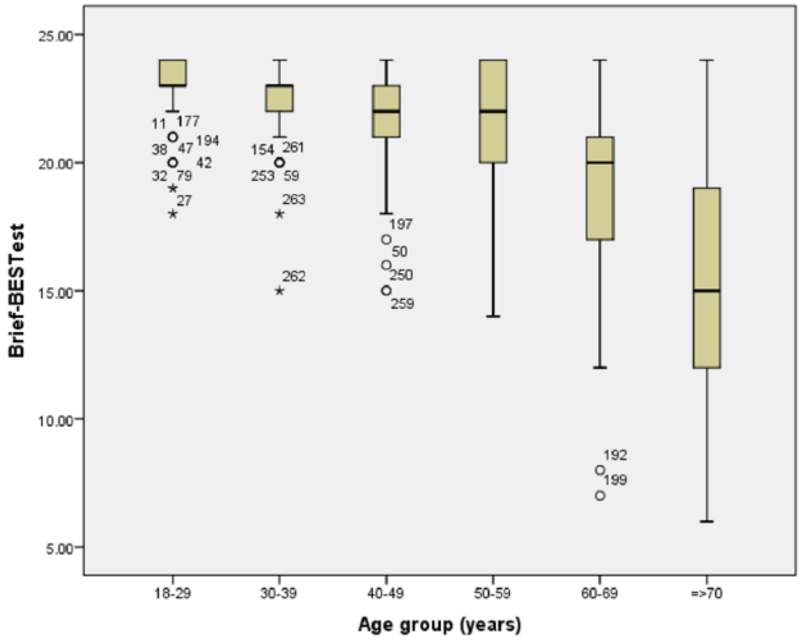
Males had significantly lower scores in the biomechanical constraints subscale than females in the 30-39 years age group ($p < 0.001$). Also, 60-69 years participants had lower scores than those who were younger than 50 years in this subscale ($p < 0.05$). Females who were 60 years or older had lower scores than males in the stability limits subscale than the males in the same age groups ($p < 0.05$). Participants who were in the 18-29 years age group had significantly higher scores than those in the 40-49 and 60-69 years age group ($p < 0.05$), and participants who were 60-69 years had significantly lower scores than adults in the 30-39 and 50-59 years age groups ($p < 0.05$). Males who were 50 years or older had significantly higher scores in the transitions-anticipatory postural adjustment subscale than females in the same age group ($p < 0.05$). In contrast, females had higher scores than males in the 18-29 age group ($p = 0.01$). For this subscale, adults who were 60-69 years had significantly lower scores than those who were 18-49 years ($p < 0.05$). Males had significantly lower scores in the reactive postural response subscale than females in the 30-39 years age group ($p = 0.005$), but they had higher scores than females in the ≥ 70 years age group ($p = 0.006$). Females who were 60 years or older had significantly lower scores in the stability in gait subscale than males in the same age groups ($p < 0.05$). In the 30-39 age group, females had performed better than males on brief-BESTest ($p = 0.005$). Males had instead performed better on brief- BESTest in 60-69 and ≥ 70 age groups ($p < 0.05$). Brief-BESTest scores were significantly lower in the adults who were 60 or older than other age groups ($p < 0.05$). Also, those who were 50-59 years had significantly lower scores than participants who were 18-29 years ($p = 0.05$). There was no other significant difference between age groups and genders regarding the brief-BEST total score and its subscales scores ($p > 0.05$).

Brief-BESTest total score and all its subscale scores based on participants' occupations and educational level are shown in Table IV. There were significant differences between people with different educational levels in the brief-BESTest total score, biomechanical constraints, and stability limits subscales, as people with higher educational levels had higher scores ($p < 0.05$). Also, People with the educational degree of lower than diploma had lower scores in the transitions-anticipatory postural adjustment, sensory orientation, and stability in gait subscales than people with higher educational levels ($p < 0.05$). People with an educational level of higher than diploma had higher scores in the reactive postural response subscale than people with lower educational levels ($p < 0.05$). There were also significant differences between occupations across brief-BESTest total score and all its subscales' scores ($p < 0.05$), except sensory orientation subscale ($p = 0.088$).

## Discussion

The present study provided the normative values of mini-BESTest and brief-BEST test scores for healthy Iranian adults. In addition, we found that the mini-BESTest and brief-BEST test scores decreased as the age increased. There were no significant differences between genders

Fig. 2. Brief-BESTest total scores across age groups. Middle thick line, median; bottom box, first quartile; upper box, third quartile; lower whisker, minimum (excluding outliers and extremes); upper whisker, maximum (excluding outliers and extremes); circle, outlier; star, extreme value. Numbers beside the stars and circles indicate the code of the subject.




on mini-BESTest and brief-BEST test scores except that the young females performed better than young males, and older males performed better than the older females on brief- BESTest. As far as we know, this is the first study that provided normative values for the mini-BESTest and brief BEST test in the healthy Iranian population.

Our study found that the ability of the participants to maintain their balance decreased with increases in age, which is in line with previous studies [30, 35-37]. The age-dependent decrease in balance performance was especially apparent in participants who were ≥ 60 years old [36]. Decreases in balance with increased age might be explained by age-related declines in various sensory (vision, vestibular), neuromusculoskeletal and somatosensory systems [38-44].

Normative values of mini-BESTest in 50-59, 60-69, and +70 years age groups (median range from 23 to 26) were almost similar to those reported by O'Hoski et al. (median range from 20 to 26). These findings indicate the similarity in dynamic balance test of mini-BESTest score regardless of nationality, Iranians or Canadians. However, the normative values of brief-BESTest in those age groups were lower for Iranian compared to Canadians, and differences between the two populations even increased with age. The possible reason might be that the Iranians scored low value in the biomechanical constraints and stability limits sections of the brief- BESTest while those items are removed in mini-BESTest. Differences in the height of the Iranian and Canadian populations could be another reason for differences in values scored on the brief- BESTest as the height can affect the Functional Reach Test (FRT) value scored by subjects [45]. The FRT is used to assess the stability limits of brief-BESTest; Canadians were taller (mean 170 cm) than Iranians (166 cm) in age groups of ≥ 50 years that can explain their better performance in the section brief-BESTest (mean range 2.2-2.7 *vs* 2.0-2.4). These differences between Iranians and Canadians could also be attributable to the low measurement precision at the individual level of the brief-BESTest, in which individual items have a greater weight on the total score. Iranians had lower scores in the transitions–anticipatory postural adjustment section than Canadians. Both tests, mini-BESTest, and brief-BESTest have included the section transitions-anticipatory postural adjustment. However, the transitions-anticipatory postural adjustment section is scored 2 out of the total 28 scores in mini-BESTest compared to 6 scores out of the total 24 scores in brief-BESTest [30], which could contribute to the lower value on the brief-BESTest in Iranians compared to the Canadians.

The IQRs for brief-BESTest total score increased with age among our sample in line with those reported previously for Canadians [30]. Brief-BESTest items are scored on a scale from 0 to 3. Subsequently, more variability and thus higher IQR for total score may be expected when using the brief-BESTest. The highest IQRs were observed for age ≥ 70 on the mini-BESTest and brief-BESTest. The high variation observed in older participants could be due to the differences in the activity level [30] and age-related comorbidities [46]. In this study, participants' activity level and medical status for possible comorbidities were not examined. Another reason might be the ability of the mini-BESTest and brief-BESTest to detect the variations in older adults.

Nevertheless, the increased IQR with age using mini-BESTest and brief- BESTest in older people needs further examination.

Males performed better than females in older age groups. However, younger females performed better than younger males. One possible reason for better balance ability in young females and older males might be their higher level of physical activity. Further investigations with both genders are needed to verify these findings.

We found a decline in all mini-BESTest subscales' scores, except in sensory orientation subscales, in which the median did not decrease across age groups. We found a similar pattern in the brief-BESTest as the sensory orientation subscale scores did not change dramatically across age groups. This finding aligns with O'Hoski et al.'s findings as there was no considerable change in the sensory orientation subscale scores in the brief-BESTest and BESTest, except in the 80-89 years age group, in which there was a clinically significant decline in this subscale's score. Such finding, especially in the case of brief-BESTest, may be due to using a foam with a medium firmness to evaluate this subscale [12]. Studies have shown that foams with lower firmness induce greater postural sway than firm ones, and individuals' performance in standing on foam with open or closed eyes is an interaction between age and foam's firmness [47]. Using a foam with low firmness may enhance the ability of brief-BESTest and mini-BESTest to detect the age-related changes in the sensory orientation subscale, and future studies are needed in this regard.

We found the greatest age-related decline in biomechanical constraints and transitions–anticipatory postural adjustment subscales of brief-BESTest, which is in line with O'Hoski et al.'s findings [30]. Hip strength affects the hip/trunk lateral strength item, which has been used to evaluate biomechanical constraints in the brief-BESTest [12, 26]. Hip muscles strength decreases by age, especially in females [48], which may be a reason for such decline in older participants' performance of biomechanical constraints subscale. Therefore, interventions and rehabilitation programs to increase the hip muscles strength may be beneficial to improve the postural balance in older adults. Such interventions also positively affect the subjects' performance in the one leg stance test, which has been used for the evaluation of transitions–anticipatory postural adjustment subscales [49]. Effects of programs that strengthen the hip muscles on individuals' performance in biomechanical constraints and transitions–anticipatory postural adjustment subscales suggest them as effective interventions as they target two balance systems, which shown greatest declines in older adults.

### Limitations

We had several limitations for this study. First, our results may not be applicable to other countries, especially countries that are much different from Iran in terms of lifestyle and health conditions, and there should be more studies in other countries to obtain the exact values of the tests for other countries. Second, we only evaluated the healthy adults, and in the clinical setting, patients, especially older adults, may have comorbidities that may affect their balance, and these findings may not be applicable to these patients. Therefore, there is a need for future studies to evaluate the normative values of mini-BESTest and brief-BESTest in patients with comorbidities. Third, we only evaluated participants' gender, and age as demographic characteristics, and future studies evaluating the association between normative values of these balance tests and other variables such as job may increase the utility of these tests.

## Conclusions

In conclusion, this study provided the normative values of mini-BESTest and brief-BESTest for healthy Iranian adults in age decades. The values provided for mini-BESTest and brief-BESTest can be used as reference values when assessing balance in healthy adults and subjects with balance dysfunctions.

## Acknowledgments

This work was supported by the Students Scientific Research Center of Tehran University of Medical Sciences (grant number: 94-03-61-29893).

## Conflict of interest statement

Authors have no conflict of interest to declare.

## Authors' contributions

Conceptualization: SN, ANA; Methodology: SN, ANA; Software: FD, ANA; Validation: ANA; Formal analysis: ANA, FD; Investigation: ANA, NN, PV, MK, MM, FD; Resources: ANA, SN; Writing - Original Draft: ANA; Writing - Review & Editing: All authors; Supervision: SN, NNA; Project administration: ANA, SN; Funding acquisition: ANA, SN.

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Received on August 1, 2023. Accepted on March 18, 2024.

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**How to cite this article:** Nakhostin-Ansari A, Naghshtabrizi N, Mohammadzadeh M, Naghdi S, Delavari F, Khalifeloo M, Vezvaei P, Ansari NN. Balance measures of mini and brief balance evaluation system tests for Iranian population. J Prev Med Hyg 2024;65:E83-E92. https://doi.org/10.15167/2421-4248/jpmh2024.65.1.3051