Relationship between Dynamic Trunk Balance and the Mini-Balance Evaluation Systems Test in Elderly Women

Yasuhiro Takahashi1, Kimio Saito2, Toshiki Matsunaga2, Takehiro Iwami3, Daisuke Kudo1, Kengo Tate3, Naohisa Miyakoshi1 and Yoichi Shimada1

1Department of Orthopedic Surgery, Akita University Graduate School of Medicine, Akita, Japan
2Department of Rehabilitation Medicine, Akita University Hospital, Akita, Japan
3Department of Systems Design Engineering, Akita University Graduate School of Engineering Science, Akita, Japan

Abstract

Objectives: Among elderly individuals, falls are major contributors to becoming bedridden, and evaluating and preventing the risk of falls is thus important in the elderly. Trunk balance stability is important to prevent falling. To safely measure trunk balance function, we have developed a dynamic balance-measurement device that is used with the subject in a sitting position. This Mini-Balance Evaluation Systems Test (Mini-BESTest) is a simple balance evaluation test that appears useful for detecting problems with balance function. The purpose of this study was to examine the relationship between dynamic trunk balance and findings on the Mini-BESTest in elderly women.

Methods: Participants comprised 31 healthy women >60 years old. Evaluation items were the Mini-BESTest total score; dynamic sitting balance, static postural balance, and muscle strength (back muscle, iliopsoas muscle, and quadriceps).

Results: Mean total Mini-BESTest score was 21.1. Mean dynamic sitting balance measured as total center of gravity (COG) trajectory length was 1447.5 mm. A negative correlation (r=-0.382, p=0.034) was observed between total COG trajectory length and BESTest score. No correlations were evident between total COG trajectory length, stationary standing COG, and muscle strength.

Conclusion: In elderly women, trunk balance in dynamic sitting correlated negatively with total Mini-BESTest score.

Keywords: Dynamic trunk balance; Mini-Balance Evaluation Systems Test (Mini-BESTest); Elderly women

Introduction

The aging of the population in Japan has progressed rapidly [1]. This rapid level of aging is expected to continue. As a result, bedridden elderly individuals are expected to increase with the increasing proportion of elderly among the population. Dementia, cerebrovascular disease, senility, fractures, and falls are major contributors to elderly individuals becoming bedridden. In addition, about 70% of fractures leading to a bedridden status involve the femur, and about 90% of femoral fractures are caused by falls [2]. Preventing falls is thus very important in the elderly [2,3].

Risk factors for falls include visual impairment, cognitive impairment, decreased balance function, muscle weakness, walking, dizziness, and medications [4]. In addition, particularly for the elderly, minimization of the deteriorations in balance function and muscle strength that occur with age is extremely important [4,5].

Trunk stability is important in balance function and is related to fall prevention [5]. Elderly individuals can also gain core stability through core training [6]. Increasing trunk balance function may thus be useful in preventing falls among the elderly.

Various evaluations are available for balance function, including the Functional Reach Test (FRT), which is based on a single task [7], tests that evaluate the sway of the centre of gravity (COG) in a stationary position [8], and assessments comprising a battery of tasks, such as the Berg Balance Test (BBS) [9]. All these evaluations can measure balance function, but do not indicate what kind of problem is present, potentially making appropriate interventions difficult to determine.

To address this problem, the Balance Evaluation Systems Test (BESTest) was developed as a balance evaluation test [10]. This test was reported in 2009 and has been translated from English for availability worldwide [11]. This test measures problems associated with balance function based on six factors: (1) biomechanical constraints; (2) stability limits/verticality; (3) anticipatory postural adjustments; (4) postural responses; (5) sensory orientation; and (6) gait stability. These six factors yield 27 item tests (Table 1). However, since the BESTest has 27 measurement items, each session of measurement requires >40 min. To address this problem, the Mini-Balance Evaluation Systems Test (Mini-BESTest) was developed as a simplified version of BESTest [12]. This test selected 14 elements from four factors that are considered the minimum necessary for evaluating dynamic balance function from among the 27 elements of the six factors of BESTest (Table 2). Mini-BESTest takes about 15 min to complete. The maximum score for this test is 32 points. Subjects with less than 19 points were judged to have no balance ability for walking [13]. Godi et al. reported a change of 4.0...
as clinically significant [14]. In addition, in a report examining Mini-BESTest scores and falls, the cutoff value predicting falls was reported as 20 for individuals with Parkinson’s disease [15] and 17.5 for individuals with chronic stroke [16].

Biomechanical constraints | Stability limits/vertically | Anticipatory postural adjustments | Postural responses | Sensory orientation | Stability in gait |
---|---|---|---|---|---|
3. Ankle strength | 8. Functional reach lateral (left and right) | 11. Stand on one leg (left and right) | 16. Compensatory stepping correction, forward | | 23. Walk with head turns, horizontal |

**Table 1: Summary of BESTest 27 items Under Each System Category.**

Biomechanical constraints | Stability limits/vertically | Anticipatory postural adjustments | Postural responses | Sensory orientation | Stability in gait |
---|---|---|---|---|---|
9. Sit to stand | | | | 19. Sensory integration for balance (modified CTSIB) Stance on firm surface, EO Stance on firm surface, EC Stance on foam, EC | |
10. Rise to toes | | | | | 22. Change in gait speed |
11. Stand on one leg (left and right) | 16. Compensatory stepping correction, forward | | | | 23. Walk with head turns, horizontal |
17. Compensatory stepping correction, backward | | | | | 24. Walk with pivot turns |
18. Compensatory stepping correction, lateral (left and right) | | | | | 25. Step over obstacles |

**Table 2: Summary of Mini-BESTest 14 items.**

When lumbar kyphosis increases in the elderly, the sway of the COG in the standing position increases, and finally trunk balance function deteriorates [17,18]. Methods for assessing trunk balance include the standing COG swing test using force plates, the FRT, and the Timed up and Go Test [19]. However, these evaluation methods do not exclude the effects of the lower limbs. In addition, for the elderly,
these test themselves are associated with a risk of falling due to various factors, potentially making the evaluation itself dangerous and difficult.

We developed a balance-measuring device that can be used in a dynamic sitting position to safely measure balance function [20]. Because this device applies a disturbance load while the subject is seated, dynamic trunk balance alone can be tested. In addition, elderly individuals are safe during this test because they remain in a seated position.

To the best of our knowledge, no previous studies have examined the relationship between dynamic trunk balance and the Mini-BESTest. The purpose of this study was thus to examine the relationship between dynamic trunk balance and Mini-BESTest in elderly women.

**Methods**

**Patients and study design**

Participants in this study comprised 31 female volunteers >60 years old with no obvious brain or nerve disorders or joint diseases, and who could walk independently.

Evaluation items were the Mini-BESTest, dynamic sitting balance, static postural balance, and muscle strength (back muscle, iliopsoas muscle, and quadriceps). The protocol was approved by the ethics committee at our institute. Written informed consent to participate in this study and for publication of the results was obtained from all patients.

**Evaluation items and equipment**

Dynamic sitting balance was measured using a dynamic sitting balance-measuring device that we developed and have reported previously [20]. This device tilts to a maximum of 3° on both sides by means of a direct current motor (BHM62MT-G2; Oriental Motor, Tokyo, Japan). COG is calculated with three triaxial force sensors (USL06-H5; Tec Gihan, Kyoto, Japan) arranged under the seat surface. The subject sat on the device with arms folded across the anterior chest, eyes open, and feet off the floor. We applied external stimuli to the subject by automatically tilting the seat of the device to the right. Dynamic trunk sway during external stimuli was measured as the COG trajectory for 30 s, and the ability to respond to external stimuli was assessed. Total COG trajectory length was considered to offer an indicator of dynamic postural balance. The test was performed twice, with the mean of the two scores used for analysis.

Static postural balance was measured using a stabilometer (UMBAR; Unimec, Tokyo, Japan). COG deviation was recorded using a microcomputer with the participant standing unaided in the upright position with eyes open for 30 s, then with eyes closed for 30 s. Total movement of the COG during measurement was calculated as the total COG trajectory length.

To assess muscle strength, the iliopsoas and quadriceps muscles were measured twice on each side with a hand-held dynamometer (Power Track II; JTEC Med, Salt Lake City, UT), and mean values of the left and right sides were used. Back muscle strength was measured twice as isometric muscle strength using a strain gauge (DPU-1000 N digital force gauge; Imada, Toyohashi, Japan) with the subject in the prone position, and the maximum value was used.

**Statistical analysis**

Spearman’s rank correlation coefficient was used to investigate the relationship between total COG trajectory length for dynamic sitting balance and the Mini-BESTest total points, COG sway in a standing position, and muscle strength. Data were analysed using SPSS for Windows version 19.0 (SPSS, Chicago, IL). Values of p<0.05 were considered statistically significant.

**Results**

Table 3 shows the background characteristics of subjects. Mean age was 73 years (range, 64-87 years). Table 4 shows the results for each item of the Mini-BESTest. Almost all participants attained maximum scores for elements No. 9 (sit to stand), No. 19 (Sensory integration for balance), and No. 20 (Incline, eyes closed). Conversely, items No. 11 (stand on one leg) and No. 27 (Timed "Get Up and Go" test with dual task) showed low scores.

<table>
<thead>
<tr>
<th>Baseline characteristics</th>
<th>No. of subjects (n)</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Body mass index (kg/m^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of subjects (n)</td>
<td>31</td>
<td>73 ± 6</td>
<td>150 ± 6</td>
<td>52 ± 8</td>
<td>23.3 ± 3.9</td>
</tr>
</tbody>
</table>

*Note*: Values are given as the mean ± standard deviation.

**Table 3**: Baseline characteristics of the participants.

<table>
<thead>
<tr>
<th>Biomechanical constraints</th>
<th>Stability limits/verticality</th>
<th>Anticipatory postural adjustments</th>
<th>Postural responses</th>
<th>Sensory orientation</th>
<th>Gait stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>2.0 ± 0.0</td>
<td>19</td>
<td>Stance on firm Surface eye open 2.0 ± 0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1.6 ± 0.7</td>
<td>22</td>
<td>1.8 ± 0.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>0.7 ± 0.8</td>
<td>16</td>
<td>1.4 ± 0.7</td>
<td>23</td>
<td>1.2 ± 0.6</td>
</tr>
<tr>
<td>17</td>
<td>1.1 ± 0.5</td>
<td>20</td>
<td>2.0 ± 0.2</td>
<td>24</td>
<td>1.7 ± 0.5</td>
</tr>
</tbody>
</table>
Table 4: Results for 13 items of Mini-BESTest.

The three items for "postural responses" (Nos. 16, 17, and 18) also had low scores. Mean total Mini-BESTest score was 21.1 (Table 5). Table 6 shows total COG trajectory length for the dynamic sitting position, stationary standing COG sway test, and muscle strengths of the back, iliopsoas, and quadriceps. Total COG trajectory length in dynamic sitting was 1448 mm.

Table 5: Average of Mini-BESTest total score.

Table 6: Average of Total length of COG (Dynamic sitting balance and static postural balance) and Muscle strength.

A negative correlation ($r=-0.382$, $p=0.034$) was observed in total COG trajectory length and Mini-BESTest total score (Figure 1). No correlations were apparent between total COG trajectory length, stationary standing COG, and muscle strength (Table 7).

Discussion

We hypothesized that dynamic trunk balance in older women would be related to findings on the Mini-BESTest. Supporting this hypothesis, a negative correlation was found between total COG trajectory length and Mini-BESTest total score. Balance function is considered to decrease with age [21], and Mini-BESTest total score in elderly women was similarly low. Furthermore, in this study, a negative correlation was seen between total COG trajectory length in dynamic sitting and Mini-BESTest total score, suggesting that declines in dynamic trunk balance ability may be associated with low Mini-BESTest scores.

In the " anticipatory postural adjustments " item, No. 11 (stand on one leg) scored particularly low. We thought that single-leg standing might thus offer an important marker of balance function. Trunk function is related to stability when standing on one leg, and activity of the trunk muscles on the standing leg side is thought to increase to...
stabilize the pelvis against the increased load on the single supporting leg [22]. Although no relationship was identified between static postural balance with eyes open (COG swing in standing with both legs) and Mini-BESTest in this study, the relationship between total COG trajectory length in one-leg standing and dynamic sitting balance in the Mini-BESTest may have been due to trunk muscle function.

"Postural response" items also showed low scores. Reactions in forward and backward directions were considered to be influenced by sagittal plane alignment in the elderly. With age, alignment of the sagittal plane of the spine becomes more kyphotic. Spinal alignment imbalances in older adults are known to cause decreases in balance function and are associated with falls [23-26]. Deterioration of the dynamic element "postural responses" was thus also considered to be related to static alignment.

Some limitations need to be considered when interpreting the present results. First, the study group was small and limited to older women. Second, muscle strength of the trunk was not measured. Back muscle was measured in this study because back muscle function is known to correlate with falls [24]. However, the newly developed dynamic sitting balance device could measure trunk dynamic balance function only by quantifying total COG trajectory length. This device was useful for comparison with other people.

Finally, we did not evaluate spinal alignment radiographically. In the future, we would like to measure spinal alignment in detail and investigate how static factors affect dynamic trunk function.

As mentioned at the beginning, preventing falls in bedridden elderly individuals is important. We plan to continue investigating how dynamic trunk balance evaluations using this device are affected by osteoporosis treatment, spinal correction surgery and rehabilitation interventions, and which specific items in the Mini-BESTest are affected.

**Conclusion**

In elderly women, trunk balance in dynamic sitting correlated negatively with Mini-BESTest total score. Future studies should investigate how the Mini-BESTest can be used in selecting optimal treatment interventions for preventing falls and the efficacy of those interventions.

**Acknowledgements**

The authors wish to thank Sumito Musaka, Atsuko Harata, and Masamichi Suzuki for their assistance in data acquisition and development of the sitting device.

**Conflict of Interest**

No potential conflict of interest relevant to this article was reported.

**References**

significance of kyphotic posture and muscle strength. Osteoporos Int 15: 1004-1010.