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Research Article

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

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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

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[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].

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
1. Base of support	6. Sitting verticality (left and right) and lateral lean (left and right)	9. Sit to stand	14. In-place response, forward	19. Sensory integration for balance (modified CTSIB) Stance on firm surface, EO Stance on firm surface, EC Stance on foam, EO Stance on foam, EC	21. Gait, level surface
2. CoM alignment	7. Functional reach forward	10. Rise to toes	15. In-place response, backward		22. Change in gait speed
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
4. Hip/trunk lateral strength		12. Alternate stair touching	17. Compensatory stepping correction, backward		24. Walk with pivot turns
5. Sit on floor and stand up		13. Standing arm raise	18. Compensatory stepping correction, lateral (left and right)	20. Incline, EC	25. Step over obstacles
					26. Timed ”Get Up & Go” Test
					27. Timed ”Get Up & Go” Test with dual task

Abbreviations: CoM: Center of Mass; ROM: Range Of Motion; CTSIB: Clinical Test of Sensory Integration for Balance; EO: Eyes Open; EC: Eyes Closed

Table 2: Summary of Mini-BESTest 14 items.

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 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)	20. Incline, EC	25. Step over obstacles
					27. Timed "Get Up & Go" Test with dual task

Abbreviations: CTSIB: Clinical Test of Sensory Integration for Balance; EO: Eyes Open; EC: Eyes Closed

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 left or 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 (UM-BAR; 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: Baseline characteristics of the participants.

Baseline characteristics	
No. of subjects (n)	31
Age (years)	73 ± 6
Height (cm)	150 ± 6
Weight (kg)	52 ± 8
Body mass index (kg/m^2)	23.3 ± 3.9
Note: Values are given as the mean ± standard deviation	

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 4: Results for 13 items of Mini-BESTest.

Biomechanical constraints	**Stability limits/ verticality**	**Anticipatory postural adjustments**		**Postural responses**		**Sensory orientation**		**Gait stability**	
		9	2.0 ± 0.0			19	Stance on firm Surface eye open 2.0 ± 0.0 Stance on foam eye closed 2.0 ± 0.4		
		10	1.6 ± 0.7					22	1.8 ± 0.4
		11	0.7 ± 0.8	16	1.4 ± 0.7			23	1.2 ± 0.6
				17	1.1 ± 0.5	20	2.0 ± 0.2	24	1.7 ± 0.5
				18	1.1 ± 0.5			25	1.7 ± 0.5
								27	0.9 ± 0.7

Note: All 27 items were scored between 0, 1, 2, points. Values are given as the mean ± standard deviation.

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.

Average of Mini-BESTest	
Mini BESTest total score (28)	21.1 ± 3.3
Values are given as the mean ± standard deviation	

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

Dynamic sitting balance	
Total length of COG (mm)	1447.5 ± 454.5
Static postural balance with eyes open	
Total length of COG (cm)	84.1 ± 43.6
Back extensor strength (N)	153.7 ± 69.0
Iliopsoas muscle strength (N)	121.7 ± 27.5
Quadriceps muscle strength (N)	147.5 ± 30.0
Values are given as the mean ± standard deviation.	
COG: centre of gravity; N: Newton ($kg/m/s^2$)	

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).

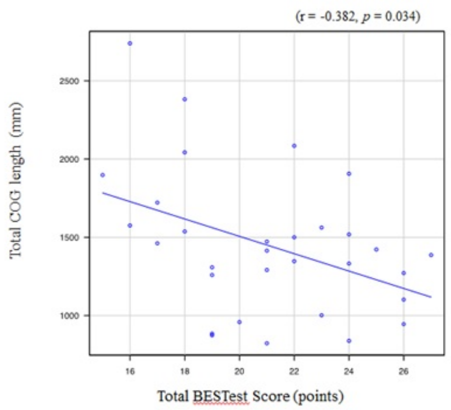

Figure 1: Correlation diagram of Mini-BESTest and Total COG length.

Table 7: Correlation with Dynamic sitting balance total length of COG. *p<0.05.

	Correlation coefficient (r)	p value
Mini-BESTest total score	-0.382	0.034*
Static postural balance with eyes open	0.248	0.177
Back extensor strength	-0.304	0.096
Iliopsoas muscle strength	-0.18	0.332
Quadriceps muscle strength	-0.222	0.23

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 sufficiently 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.

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CONFLICT OF INTEREST

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

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