Changes in Performance on the Balance Board Test and Motor Fitness over Time in Elderly Women

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Abstract The balance board (BB) test is used to assess balance ability, but, with age, individuals become unable to successfully perform the test. Our objective was to investigate the changes in performance on the BB test and motor fitness over time in elderly women. A total of 52 elderly women who were able to stand on both legs on a rocking unstable board for 20 s were enrolled. Subjects were classified into two groups according to their ability to perform the task 1 year later [able group (A); n = 35] or not [unable group (U); n = 17]. The results of our analysis indicated that the height of women in the U group had decreased over the 1-year period. At both time points, the women in the U group had worse one-leg standing and walking times than those in the A group. Our findings indicate that inferior motor fitness in the pre-stage and reduced height after 1 year are factors that contribute to the poor performance of elderly people on the BB test.

Keywords: annual change, dynamic balance ability, unstable board

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1. Introduction

Aging is accompanied by marked decrease in physical functions, which is associated with an increased need for nursing care. However, the effect of age-related problems can be reduced or controlled by maintaining and increasing physical functions. Therefore, it is important to regularly ascertain the physical functions of elderly people in the community in order to detect the changes in these abilities and examine methods of intervention.

Previously, simple tests conducted at any location were selected to assess the physical functions of elderly people. One example of such a test is the “Physical fitness test by the Ministry of Education, Culture, Sports, Science and Technology of Japan.” This test assesses the isometric grip strength (muscle function), open-eyed one-leg standing (neurological function), anteflexion in a straight-legged position (joint function), and 6-minute walking. In addition, a test including typical activities of daily living (ADL) can be represented by the 10-meter walk test (10-MWT) with obstacles, the timed up-and-go test, and the cross-step moving on four spots test [1]. Many of these tests assess the physical fitness and motor fitness individually based on the measured values. However, most people are able to perform these tasks, and owing to the low level of difficulty of these tasks, even for elderly people who require nursing care, these tests may not provide an adequate assessment of physical functions.

The balance board (BB) test is designed to assess the ability of elderly people to maintain position on an unstable board and utilizes unpredictable stimuli [2,3]. It has been used to assess the physical functions and risk of falling in active elderly people. Because this test involves a board that is not fixed in place (an unstable board) and the board’s position changes with the subject’s balance, the subject must have sufficient balance to maintain position under unstable conditions in order to successfully perform the test. Owing to the high level of difficulty of this task, some elderly people are unable to perform the test. Sugiura et al [3] reported that elderly people unable to perform the BB test have had more falls and have a decreased balance and walking abilities and ADL in comparison to elderly people who are able to complete the tasks of the BB test. A longitudinal investigation is required to identify the reason why some individuals are unable to perform the task [4]. Longitudinal studies of changes in the motor fitness and cognitive function associated with interventions include studies by Liu-Ambrose et al [5] and Muscari et al [6], conducted for approximately 1 year, and studies by Tsutsumi et al [7] and Maki et al [8], conducted for approximately 3 months. As such, the intervention duration of the studies differ; however, because elderly...
people experience an annual decline in physical functions of approximately 1% [9,10], it is important to investigate the changes occurring over the span of 1 year.

The objective of our study was to conduct a longitudinal investigation of the performance on the BB test and the motor fitness in elderly people.

2. Methods

2.1. Subjects

We enrolled 52 elderly women who were able to independently engage in daily activities and participated once every week or every other week in health classes or social education programs held by their local municipality. They underwent measurements for 2 continuous years (2015 and 2016 or 2016 and 2017) in either August or September. After detailed explanations of the purpose and procedures of this study, all subjects willingly signed informed consent. The Ethics Committee on Human Experimentation of Fukui University of Technology approved the experimental protocol (Ref. No. 2015-1).

2.2. Balance Board Test (BB test)

In BB test, we used the DYJOC Board (SAKAI Medical, Japan). This device comprises a flat board with two dome-shaped hubs attached to its underside. The board tilts a maximum of 17 degrees to the right and left. The sensor attached to the board detects tilts in all directions during testing, and the measured values thus obtained are recorded on a computer using the device’s data log. Using previous studies as references, the subjects were instructed to perform two-leg standing periods of 20 s on the unstable board that was rocked only to the left and right. They performed this task twice with a 1-min rest period between the two attempts. The attempts were considered failures if the edges of the board contacted the floor during testing or if either of the subject’s feet contacted the ground. The 52 subjects who succeeded at this task on both attempts were classified according to their ability to succeed again 1 year later into the able group [(A); n = 35] and unable group [(U); n = 17].

We also assessed the following variables: stability index (angle changes of the board during testing, using the horizontal as the standard line), range of angular fluctuation (the range within which the angle of the board fluctuated during testing, using the mean angle of incline as the standard), and total angular fluctuation index (the total board angle degree change during testing). In all cases, we interpreted higher values to be indicative of lower balance ability and vice versa. We also selected representative values from the second attempt.

2.3. Physical Characteristics and Motor Fitness

We assessed the physical characteristics by measuring height, body weight, and bone density according to time point and group, and the differences between their means based on the test results. Only with respect to height, a significant difference was found between groups; subjects in group U had lower heights after 1 year than initially. The main effect in the time point factor was observed for age and weight. Age was higher after 1 year, but weight was higher initially. The effect size was large for time and interaction factors ($\eta^2 = 0.17–0.80$).

Table 1 shows the baseline statistical values for all variables related to the BB test in both groups, and the differences between their means based on the test results. We found significant differences for all variables, with subjects in group A having higher values than those in group U. The effect size was moderate or larger ($d = 0.60–1.03$).

Table 2 shows the statistical values for age, height, body weight, and bone density according to time point and group, and the differences between their means based on the test results. We found significant differences for all variables, with subjects in group A having higher values than those in group U. The effect size was moderate or larger ($d = 0.60–1.03$).

Table 3 shows the statistical values for all variables related to the BB test at both time points for subjects in group A, and differences between their means based on the test results. We found no significant differences in any of the variables examined.

Table 4 shows the statistical values for motor fitness according to time point and group, and the differences between their means based on the test results. We found no significant interactions for any of the variables. The main effect in the group factor was observed for one-leg standing and 10-meter walking times; at both time points, subjects in group U had lower values than those in group A. The effect size was moderate or larger ($\eta^2 = 0.08, 0.10$).
Aging is accompanied by a decrease in physical fitness and motor fitness. Thus, when conducting research affected individual will tend to display low physical comparison standards to assess individual physical fitness and motor fitness. Thus, when conducting research on elderly people, age and physical characteristics must be considered. Our results indicated a lack of significant intergroup differences in any of the aforementioned variables at either time point, and we were able to interpret the groups as being composed of similar populations.

### 4. Discussion

Aging is accompanied by a decrease in physical fitness and motor fitness, and statistical analyses can produce comparison standards to assess individual physical characteristics such as height, weight, and bone density. If the measured values are lower than the standard, the affected individual will tend to display low physical fitness and motor fitness. Thus, when conducting research on elderly people, age and physical characteristics must be considered. Our results indicated a lack of significant intergroup differences in any of the aforementioned variables at either time point, and we were able to interpret the groups as being composed of similar populations.

In general, physical function and motor fitness both contribute to performance. In the present study, performance on the BB test initially was worse in the U group than in the A group. In addition, the motor fitness as measured by one-leg standing and 10-MWT was worse in the U group than in the A group at both time points. The BB test examines dynamic balance ability [12]. Dynamic balance is also examined during walking tests because

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**Table 1. Statistical values for age, height, body weight, and bone density according to time point and group**

|             | Pre          |            |            |          | Post        |            |            |          |
|-------------|--------------|------------|------------|----------|-------------|------------|------------|----------|
|             | M  | SD | MAX | MIN | F  | p   | η²  | Post-hoc |
| Age         | A  | 78.17 | 5.57 | 91  | 65 | 79.11 | 5.58 | 92  | 66 | F1 | 192.7* | 0.00 | 0.88 | A, U: Pre < Post |
|             | U  | 80.71 | 5.79 | 91  | 69 | 81.76 | 5.84 | 92  | 69 | F2 | 2.91  | 0.09 | 0.06 |
| Height      | A  | 146.9 | 4.37 | 163.0 | 140.1 | 146.7 | 4.42 | 163.0 | 140.5 | F1 | 13.4* | 0.00 | 0.21 | U: Post < Pre |
|             | U  | 146.0 | 3.80 | 158.0 | 140.1 | 145.4 | 4.13 | 157.9 | 138.0 | F2 | 0.77  | 0.38 | 0.02 |
| Weight      | A  | 46.59 | 7.34 | 62.4 | 35.4 | 45.7 | 6.9 | 57.2 | 34.9 | F1 | 9.73* | 0.00 | 0.17 | U: Post < Pre |
|             | U  | 47.47 | 10.26 | 73.5 | 30.4 | 46.7 | 10.8 | 73.0 | 29.1 | F2 | 0.12  | 0.74 | 0.00 |
| Bone strength | A  | 2.27 | 0.24 | 2.79 | 1.88 | 2.31 | 0.34 | 4.00 | 1.97 | F1 | 3.66  | 0.06 | 0.07 |
|             | U  | 2.16 | 0.27 | 2.64 | 1.80 | 2.25 | 0.31 | 2.87 | 1.83 | F2 | 1.36  | 0.25 | 0.03 |

**Note** F1: Time point, F2: Group, F3: Interaction, A: Group A, U: Group U. *:p <0.05.

**Table 2. Baseline statistical values for all variables related to the BB test in both groups**

|             | Group A       |            |            |          | Group U     |            |            |          |
|-------------|---------------|------------|------------|----------|-------------|------------|------------|----------|
|             | M  | SD | MAX | MIN | t  | p   | d     |            |            |            |            |            |            |            |            |
| Stability index | 4.38 | 1.59 | 7.66 | 1.27 | 6.82 | 2.66 | 12.30 | 3.15 | 3.74* | 0.00 | 1.03 |
| Angular fluctuation range | 2.68 | 1.02 | 6.18 | 1.00 | 4.69 | 2.00 | 9.43 | 2.07 | 4.18* | 0.00 | 1.15 |
| Total angular fluctuation index | 518.3 | 308.0 | 1587.5 | 139.7 | 735.6 | 419.8 | 2095.0 | 273.9 | 2.18* | 0.03 | 0.60 |

**Note** *:p <0.05.

**Table 3. Statistical values for all variables related to the BB test at both time points for subjects in group A**

|             | Pre          |            |            |          | Post        |            |            |          |
|-------------|--------------|------------|------------|----------|-------------|------------|------------|----------|
|             | M  | SD | MAX | MIN | F  | p   | η²  | Post-hoc |
| Stability index | 4.38 | 1.59 | 7.66 | 1.27 | 4.05 | 2.00 | 11.49 | 0.52 | 1.14 | 0.26 |
| Angular fluctuation range | 2.68 | 1.02 | 6.18 | 1.00 | 2.68 | 1.55 | 8.90 | 0.40 | 0.01 | 0.99 |
| Total angular fluctuation index | 518.3 | 308.0 | 1587.5 | 139.7 | 507.1 | 350.0 | 1804.5 | 132.2 | 0.38 | 0.71 |

**Table 4. Statistical values for motor fitness according to time point and group**

|             | Pre          |            |            |          | Post        |            |            |          |
|-------------|--------------|------------|------------|----------|-------------|------------|------------|----------|
|             | M  | SD | MAX | MIN | F  | p   | η²  | Post-hoc |
| Hip flexion strength | A  | 13.02 | 3.22 | 23.1 | 8.7 | 12.71 | 4.03 | 24.2 | 6 | F1 | 2.30  | 0.14 | 0.05 |
|             | U  | 13.01 | 4.13 | 21.4 | 7.4 | 11.55 | 3.19 | 19.2 | 4.6 | F2 | 0.28  | 0.60 | 0.01 |
| Knee extension strength | A  | 8.85 | 2.24 | 13.42 | 4.43 | 8.49 | 2.75 | 18.26 | 4.63 | F1 | 0.74  | 0.40 | 0.02 |
|             | U  | 8.13 | 2.62 | 12.28 | 3.46 | 7.74 | 2.35 | 12.92 | 3.21 | F2 | 1.08  | 0.30 | 0.02 |
| One leg standing | A  | 50.84 | 37.76 | 120 | 4.2 | 53.02 | 42.22 | 120 | 6.3 | F1 | 0.76  | 0.39 | 0.02 |
|             | U  | 35.69 | 37.36 | 120 | 4.4 | 25.04 | 27.21 | 109.27 | 123 | F2 | 4.46* | 0.04 | 0.08 |
| Functional reach | A  | 33.07 | 6.55 | 52.5 | 22.5 | 31.66 | 6.89 | 50 | 16.8 | F1 | 0.18  | 0.68 | 0.00 |
|             | U  | 29.09 | 5.16 | 39.1 | 17 | 31.08 | 6.38 | 40.9 | 16 | F2 | 1.76  | 0.19 | 0.04 |
| Waking time | A  | 5.67 | 0.91 | 7.91 | 4.18 | 5.72 | 1.20 | 8.65 | 3.73 | F1 | 1.73  | 0.20 | 0.03 |
|             | U  | 6.33 | 1.31 | 9.00 | 4.24 | 6.70 | 1.79 | 10.98 | 4.48 | F2 | 5.24* | 0.03 | 0.10 |

**Note** F1: Time point, F2: Group, F3: Interaction, A: Group A, U: Group U. *:p <0.05.
people move their support base in conjunction with their balance when walking [13]. During walking tests, individuals move their body voluntarily; however, during the BB test, involuntary responses are made to unexpected stimuli. Although different balance abilities are involved in each case, our results suggest that some balance abilities are at play to some extent in both cases.

During the older years, sarcopenia causes muscle atrophy. This in turn leads to an associated decline in body weight. The women in both groups in our study showed decreased body weight after 1 year. Despite the fact that they attended health classes approximately once per week, they did not receive professional training guidance and each subject practiced regular walking and simple muscle strength training on their own. As a result, they were able to maintain their leg strength but experienced systemic muscle atrophy, which led to decreased body weight. Thus, it remains necessary to investigate trunk muscle mass and changes in muscle strength. On the other hand, a decrease in height was noted only among women in the U group. Causes of reduced height in the elderly include atrophy of the intervertebral discs in the spine, anteflexion of the posture, and osteoporosis [14]. In our study, we did not observe significant chronological changes or intergroup differences in bone density. The elderly women who were unable to perform the BB test after 1 year showed changes in their posture during the intervening year as well as changes in the strategies for maintaining their position. These factors may have been the cause of their difficulty in succeeding at the BB test. In addition, 29.4% of elderly women in the U group had articular disorder (ankle, knee, and/or hip joints) during follow-up. Future studies are required to focus on the issue of changes in posture and joint function.

Due to the fact that the subjects in the present study practiced regular physical activities, their motor fitness showed no chronological changes in either group. However, although women in the A group showed no changes in their performance on the BB test, those in the U group were unable to perform the BB test after 1 year. In addition, women in the U group showed decreased motor fitness than those in the A group during multiple exercises from the beginning. This suggests that even when motor fitness is maintained, in individuals with poor motor fitness for tasks that require balance to begin with, weakening muscles and neural functions that accompany aging can contribute to the inability to perform the BB test after 1 year. The results of performance tests with high levels of difficulty, such as those conducted in our study, performed in conjunction with conventional physical fitness tests can provide an accurate assessment of the degree to which the elderly women have become weaker.

In conclusion, the factors affecting the ability of elderly women to perform the BB test after 1 year included the initial performance on the test, a decreased motor fitness for tasks that require balance ability, and reduced height.

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Conflict of interest statement

The authors declare no conflicts of interest associated with this manuscript.

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