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The Relationship between Stepping Test, Functional Reach Test and Balance Board Test in Healthy Male Students

Hiroki Sugiura[1*] and Shinichi Demura[2]

[1]Department of Industrial Business and Engineering, Fukui University of Technology, Fukui, Japan.
[2]Graduate School of Natural Science and Technology, Kanazawa University, Ishikawa, Japan.

Authors' contributions

This work was carried out in collaboration between both authors. Author HS designed the study, wrote the protocol, wrote the first draft of the manuscript and managed the literature searches. Author SD managed the experimental process and identified the species of plant. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: Various tests to assess dynamic balance ability have been developed. The spot stepping (stepping) test assesses balance ability when a person voluntarily moves the body. The functional reach (FR) test assesses balance ability when a person is subjected to added stimulation to make the body unstable. The balance board (BB) test assesses balance ability when a person is subjected to added stimulation while continuously standing on one leg. This study aimed to examine the relationship between each of these tests with regards to dynamic balance ability.
Methodology: The subjects were 37 young males (mean age, 22.8 years; SD, 4.9 years). The time difference between the stipulated tempo (40 bpm) and the real timing of steps in the stepping test, the reach distance for the FR test and the fluctuation index for the BB test were selected as evaluation parameters. In addition, the BB test used the values obtained from the manipulating leg.
Results: A significant and moderate correlation ($r = 0.40$, $p<0.05$) was found between the stepping and the BB test. In these tests, the body receives stimulus voluntarily or involuntary. Neither the

**Corresponding author: E-mail: sugiura@fukui-ut.ac.jp;*

stepping test nor the BB test showed significant correlation with the FR test during which subjects voluntarily shift their center of gravity forward.
Conclusion: The FR test assesses a very different functional ability than the stepping and BB tests and this explains why the relationships were not high.

Keywords: Dynamic balance; stepping test; functional reach test; balance board test.

1. INTRODUCTION

Most activities in daily life rely on many factors, such as the visual system [1], vestibular system [2], somatic sensation [3] and muscle strength [4]. Balance ability plays a very important role in maintaining a stable standing posture. This ability can be divided into static balance and dynamic balance. The former is the ability to stabilize the center of gravity within a supporting base during static standing [5] and the latter is to move it to a new supporting base with the stability being interfered or to maintain a stable posture within a supporting base by body movement [6]. There are various types of dynamic balance ability test, including tests that measure voluntary movements of the body, voluntary movements of the body while subject to stimuli designed to make the body unstable and involuntary movements of the body while subject to continuous stimulation.

The stepping on the spot test, which resembles natural gait, has been developed to assess dynamic balance ability of the body when the body is moving voluntarily [7-9]. This test requires the ability to support the body on one leg at a time [7,8] and evaluates balance ability by step number and grounding time of feet within a stipulated time. Although people with superior balance ability can easily matching a step tempo slower than their usual gait, people with inferior balance ability find it difficult to maintain stability on one leg for a long time. Hence it is assumed that people with poor balance ability will have large timing errors when attempting to follow a stipulated tempo [9].

The functional reach (FR) test was developed to assess a person's ability to maintain physical stability when adding a voluntary motion designed to make the body unstable [6,10,11]. In this test, subjects are asked to reach their dominant hand out as far as possible, which upsets the center of gravity and the reach distance is measure. Because moving the center of gravity forward renders posture unstable, better balance ability exertion is necessary to maintain stable posture. Hence, it is assumed that persons with longer reach distances have superior balance ability.

The one-leg standing on an unstable moving stool test (balance board test; BB test) is used to assess the dynamic balance ability to maintain physical stability when the body receives continuous involuntary stimulation [12-14]. Because the support base fluctuates on an unstable stool at any time, subjects must maintain posture stability under an unstable situation. Fluctuation of the support base is a type of disturbance stimulation and this test requires the exertion of the balance ability differing from the above both tests. It is assumed that persons with small fluctuations in the center of gravity have superior balance ability.

The tasks involved in each of the three tests are very different. However, they have one common characteristic in that they all test ability to maintain stable posture while being subject to stimulation designed to interfere with posture. Therefore, we assumed that a subject's results on the three tests would show some degree of correlation. This study aimed to examine the relationship between the spot stepping test, functional reach test and balance board test.

2. MATERIALS AND METHODS

2.1 Subjects

We included 37 healthy male students (age: 22.8±4.9 years, height: 172.0±5.7 cm, weight: 68.6±8.9 kg). They did not performed sport. In addition, they had no history of vestibular or visual pathology, dizziness or imbalance, neurological or orthopedic problems. Subjects' manipulating leg (the leg used to kick a ball) and supporting leg (the leg used to support the body when kicking a ball) were judged using one item (Which is the leg used to kick a ball?) from the dominant leg survey developed by Demura et al. [15]. Manipulating leg of all subjects was right. The purpose and procedure of this study were explained to all participants and informed consent was obtained from participants. The present experimental protocol was approved

by the Ethics Committee on Human Experimentation of the Faculty of Education, Kanazawa University (Ref. No. 2012-03).

2.2 Stepping Test

The evaluation parameter of the stepping test was the error time between on–off times of the feet compared to a stipulated tempo, which were measured by a step sheet (Takei Scientific Instruments Co. Ltd. Japan). This device can measure in real time from when a subject's right or left foot touched the step sheet to when his foot left the step sheet, on the basis of foot pressure information. The sampling frequency was 100 Hz. The subjects stood on the step sheet and stepped while matching the tempo (40bpm) of a metronome.

After one practice trial, the stepping test was performed twice for 20 s with a 1-min rest between trials. The representative value was taken from the mean. Inferior dynamic balance ability was determined where the time difference between real time steps and the stipulated tempo was large.

2.3 FR Test

The FR test in this study was performed using an elastic stick [16]. This test does not require a large space and reach distance is easily measured. In short, it is possible to measure reach distance as simply as a conventional FR test. From an upright standing position, subjects were asked to extend their dominant hand while touching the top of an elastic stick fixed at a dominant acromion height on the wall. This elastic stick can be shortened by extending a hand forward without a large amount of force. Anti-slip material made of rubber was attached to the top of the elastic, so as not to move the contact point between the top of the elastic fixed at acromion height and the wall. Subjects were also instructed to extend their hand as far as possible without moving their feet. After one practice trial, FR testing was performed twice with a 1-min rest between trials. Their mean was used as a representative value. Short reach distances were assumed to indicate inferior dynamic balance ability.

2.4 BB Test

The DYJOC Board plus (SAKAI med, Japan) was used to evaluate balance ability while subjects stood on one leg on an unstable stool. This device (Fig. 1), which consists of the dome-shaped structure attached to the lower surface of a flat board, can slant up to 12º backward and forward and up to 7º right and left. The built-in sensor on the board detects anteroposterior and right–left gradients; measurement data was thus calculated. The fluctuation index, as described by Ogaya et al. [12], was selected as a parameter. Because this is the mean of absolute values of the total amount of angles that fluctuated during a measurement, larger values were considered to indicate inferior dynamic balance ability. Three trials lasting 30 s were measured for each leg with a 1-min rest between trials. A representative value was obtained by calculating the mean of two and three trials.

2.5 Statistical Analysis

The intra-class correlation coefficient (ICC) was calculated to examine the test-retest reliability for each parameter. The relationships between each parameter were examined by Pearson's correlation coefficient. The significance level in this study was set at $p<0.05$. Data were analyzed using SPSS version 11.0 for Windows software (SPSS Inc. Tokyo, Japan).

3. RESULTS

Fluctuation indices of BB test were better for the manipulating leg (328.6±106.3) than for the supporting leg (351.4±124.9) ($t = 2.32$, $p<0.05$). Hence, we used the former as a parameter of the BB test in this study. Table 1 shows the basic statistics, ICCs and correlation coefficient between each parameter. ICCs of each parameter were very high (0.82–0.94). A significant moderate correlation was found between the stepping and BB tests ($r = 0.40$). No significant correlation was found between any other parameters.

4. DISCUSSION

In this study, it was assumed that the stepping test, FR test and BB test could assess various dynamic balance. Noguchi et al. [14] reported that results for the manipulating leg were superior to the supporting leg results on the BB test. In this study, we confirmed that the manipulating leg was superior on the BB test (see Methods). In this study, dynamic balance ability was evaluated using results of the manipulating leg. Shin and Demura [9], Shin and Demura [17] and Honaker et al. [18] described the validity and specificity of the step test.

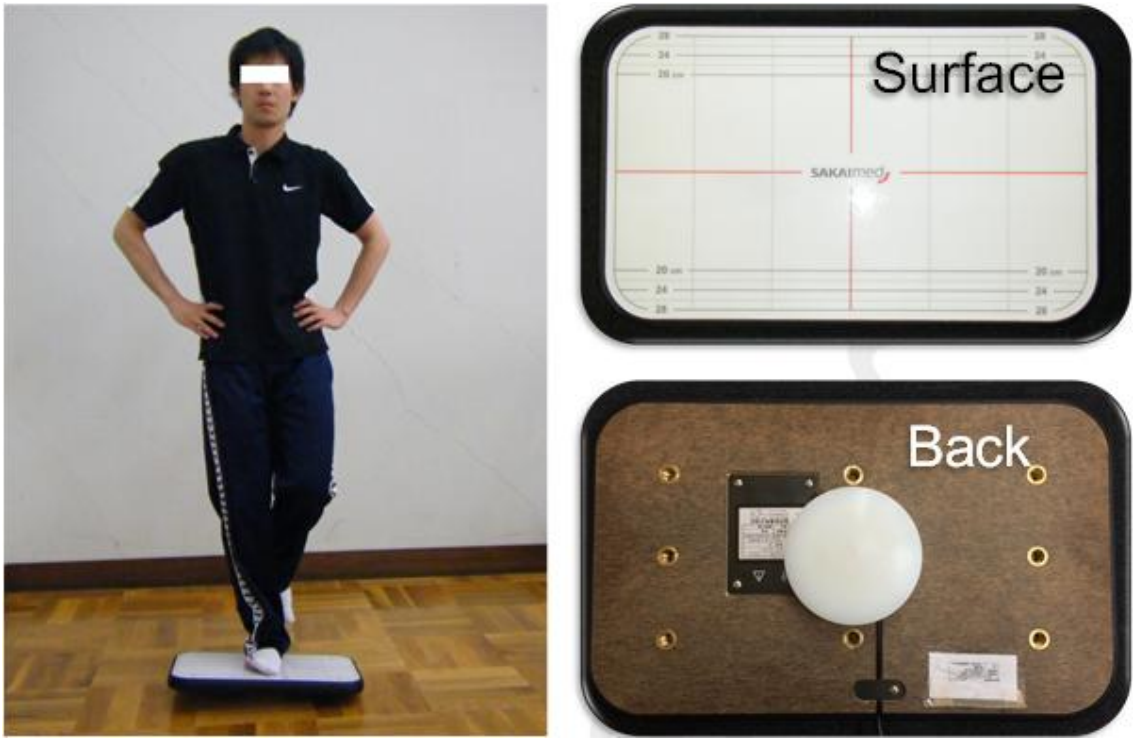

Fig. 1. The DYJOC board plus

Table 1. The basic statistics, ICCs and correlation coefficient of the between each parameter

	M	SD	MAX	MIN	ICC	r	
						a	b
a. Stepping test	0.055	0.016	0.094	0.020	0.82		
b. Functional reach test	40.54	6.86	55.0	26.0	0.94	0.05	
c. Balance board test	328.6	106.3	578.4	165.2	0.93	0.40*	0.09

*Note) M: mean value, SD: standard deviation, MAX: maximum value, MIN: minimum value, ICC: intra-class correlation coefficient, r: pearson's correlation coefficient, *: p<0.05*

Toyama and Fujiwara [19] reported that a 120-bpm (40 step/20 s) tempo was the most efficient interval during walking. Shin and Demura [9], Shin and Demura [17] and Yamaji et al. [20] reported that among 120 bpm, 60 bpm and 40 bpm tempos, which correspond to 1/2 and 1/3 intervals of 120 bpm, the 40 bpm tempo was the most challenging. Yamaji et al. [20] reported, in a study of young male subjects, that a 40-bpm tempo was more difficult than 60-bpm or 120-bpm tempo on the stepping test; therefore, the 40-bpm tempo was effective in assessing dynamic balance ability and was used in this study. In addition, it was confirmed that ICC of all tests was high (≥0.82).

All tests have one common characteristic, i.e. they all test the ability to maintain a stable posture while being subject to stimulation, which is designed to interfere with stability of the posture. No significant relationship was found between the FR test and the stepping and BB tests. Liao and Lin [21] reported a strong relationship between center of pressure (COP) displacement and ankle mobility. According to Jonsson et al. [22], movement during the FR test was characterized by a large forward rotation of the trunk and extension of the ankle. Because the movement required in the stepping test resembles normal walking, ankle movements are accompanied at heel strike and toe off. Ankle strategy is considered important on the BB test, because the ankle has a split second to adjust on an unstable moving stool. A relationship was not found between the FR test and the stepping and BB tests. Ankle movements are involved in all tests, but the mechanisms are different. In short, the foot leaves the floor during the stepping test.

The feet are grounded during the BB and FR tests. During the former extension–flexion of the ankle is continually required in all directions and during the latter only extension is required.

Takeshima and Rogers [6] reported that although the FR test is easy to administer, it only assesses one-way balance ability. Continuous COP movements involved in the stepping and BB tests differ from those involved in the FR test [9,14]. It is considered that the mechanisms of dynamic balance ability needed to maintain physical stability while subject to a disturbing stimulus (such as during the FR test) are different to the mechanisms needed to maintain dynamic balance during the stepping and BB tests.

The stepping and BB tests assessed dynamic balance ability. During the former, the body moves and during the latter, the body receives continuous involuntary stimulation. The tests are different; however, it was hypothesized that the tests were measuring related aspects of balance. A significant moderate correlation was found between the stepping and BB tests ($r = 0.40$). The BB test involves standing on an unstable moving stool with one leg and the stepping test involves matching stepping tempo on one leg. In short, an unstable situation during a one-legged standing posture exists in both tests. Hence, it is considered that the above relationship was found because both tests involve the ability to maintain stability on one leg.

Zatsiorsky and Kraemer [23] reported that even if the movement pattern of the balance test is similar, the mobilization pattern of the potential nerve–muscle involved and the proprioceptive organ feedback may be different. In addition, Kawabata et al. [24] reported a moderate relationship between tests that involve both legs to stand on an unstable moving stool and the "COP tracking tests" ($r = 0.43$) and that both types of tests assess different balance. In this study, we found a significant relationship between the stepping and BB tests; however, it was not high (determination coefficient: 16%). The tests differed in motion stimulation involved voluntary motion and the other involuntary motion. From the results of the present study, it is considered that very different functional ability is related to each of these tests.

5. CONCLUSION

All tests have one common characteristic, they all test the ability to maintain a stable posture while being subject to stimulation, which is designed to interfere with stability of the posture. As a result, the FR test is related to a different ability than the stepping and BB tests. However, the relationships between the latter two dynamic balance tests are not as high. In the next research, increasing the benefit of dynamic balance ability tests for clinical use.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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