American Journal of Sports Science and Medicine, 2016, Vol. 4, No. 1, 1-5
Available online at http://pubs.sciepub.com/ajssm/4/1/1

DOI:10.12691/ajssm-4-1-1

Effect of Achievement Possibility of a Balance Board Test on Physical Functions, ADL, Fall Experience, and Fall Risk in Elderly Females

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Abstract To maintain a stable posture on an unstable moving stool is performed by few in daily life. Hence, the achievement of a stable posture on an unstable moving stool may be difficult even for the elderly with high independence in daily activities. The passive dynamic balance ability required for the above movement has close relationships with activities of daily living (ADL) and fall risk. This study aimed to examine differences between the female elderly [possible group (PG), n = 123] who could maintain a stable posture on an unstable stool leaning sharply in the backward and forward directions for 20 s (balance board test) and those could not maintain this posture [impossible group (IG), n = 20] for physical functions, ADL, fall experience, and fall risk. Physical functions included isometric leg strength, balance ability, and walking ability. They were administered the above-stated various tests and surveys on ADL, fall experience, and fall risk. PG showed significantly lower rates of fall experience than those shown by IG. In addition, PG was superior in one-leg standing with eyes open, 10-m walking, and ADL compared with IG, but an insignificant difference was found for leg strength between both groups. In conclusion, the female elderly who cannot perform the present balance board test have more fall experience and are inferior in static balance ability, walking ability, and ADL compared with the elderly who can perform it despite having similar static leg strength.

Keywords: *maintain a stable posture, unstable stool, physical functions, fall*

Cite This Article: Hiroki Sugiura, Shinichi Demura, and Yu Uchida, “Effect of Achievement Possibility of a Balance Board Test on Physical Functions, ADL, Fall Experience, and Fall Risk in Elderly Females.” *American Journal of Sports Science and Medicine*, vol. 4, no. 1 (2016): 1-5. doi: 10.12691/ajssm-4-1-1.

1. Introduction

In old age, physical functions such as leg strength, balance, and leg joint function decrease markedly [1]. As a result, activities of daily living (ADL) are limited, and in addition, the ability to achieve ADL decreases [2]. Furthermore, the above decrease also greatly affects fall occurrence [3,4] and quality of life [5]. Hence, for the elderly, it is very important to prevent a decrease in physical functions to maintain the ability to independently perform ADL.

A balance test has been used to screen for fall risk [6,7], because balance ability in the older population has close relationships with walking ability and the fall risk [6]. It is defined as “ability to keep the center of gravity after any disturbance and has relationships with physical alignment, leg strength, leg joint function, etc., in addition to equilibrium function controlling the posture [7]. Balance ability is divided largely into static balance and dynamic balance. The former is the ability to stabilize the center of gravity (COP) within a supporting base during static standing [8], 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]. Particularly, the latter is considered to be very important for the achievement of ADL. Tests such as functional reach [9,10], spot stepping [11,12], and limits of stability [13,14] have been developed to assess dynamic balance ability. These tests assess dynamic balance ability that is exerted when a body is moving positively. Because falls generally occur incidentally, evaluating the balance ability required to keep a stable posture when the body is subjected to an external stimulus is considered to be important.

Recently, a test (balance board test) has been developed to assess dynamic balance ability; this test involves maintaining a stable posture on an unstable board [15,16,17]. Because the supporting base always fluctuates due to an unstable board, subjects need maintain a stable posture under unstable conditions. Hence, there exist persons who cannot achieve it even among the elderly with high independence in daily activities. It is assumed that they are inferior for various physical functions, including dynamic balance ability, and have higher fall risk.

This study aimed to examine differences between the female elderly who can maintain a stable posture on an unstable stool and those cannot do it for physical functions, ADL, fall experience, and fall risk.

2. Methods

2.1. Subjects

Subjects included 123 elderly females who could maintain a stable posture on an unstable stool (age: 76.6 ± 5.5 years, height: 147.6 ± 5.1 cm, weight: 49.2 ± 7.3 kg) for 20 s and 20 elderly females who could not maintain this posture (age: 79.2 ± 6.1 years, height: 146.3 ± 5.7 cm, weight: 50.4 ± 7.3 kg). They attended health classes or social educational activities hosted by municipal governments and engaged in social activities at least once per week or every alternate week. In short, they could independently perform ADL. After providing detailed explanations of the purpose and procedures of this study to all participants, we obtained their informed consent. The present experimental protocol was approved by the Ethics Committee on Human Experimentation of Fukui University of Technology (Ref. No. 2015-1).

2.2. Balance Board Test

The DYJOC Board plus (SAKAI med, Japan) was used to evaluate posture stability while standing on an unstable stool. This device, which consists of two dome-shaped structures attached to the lower surface of a flat board, can slant up to 12° in the backward and forward directions. Standing with both legs on the above device for 20 s was measured twice with a 1-min rest period between trials according to the method in the report by Ogaya et al. [15]. The trial was judged to be a failure when the edge of the stool contacted the floor more than 3 s during measurement or when either leg contacted the floor. A total of 123 subjects who could complete the trials twice were categorized into the possible group (PG), 20 subjects those who could not complete the trials twice were categorized into the impossible group (IG). Elderly subjects who successfully completed only one trial were excluded from analysis. In this study, it was assumed that PG is superior in passive dynamic balance ability compared with IG.

2.3. Leg Strength, Balance Ability, and Waking Ability

To evaluate leg strength, isometric strength of hip flexion, knee extension, and toe flexion were selected. The strength regarding each aforementioned parameter was measured by tension meter attachments (μTAS F-1, Anima Co. Ltd., Japan; T.K.K.1269f, Takei Scientific Instruments Co. Ltd., Japan) and a toe finger dynamometer (T.K.K.3361, Takei Scientific Instruments Co. Ltd., Japan). Each strength was measured once for the right and left legs, and their mean was used as a representative value. One-leg standing with eyes open and functional reach tests were used to evaluate balance ability. The former measured balance ability be determining the time taken by subjects to keep a standing posture with either leg (maximum time: 120 s). The latter was measured using an elastic stick according to the method in the report by Demura and Yamada [18]. They were asked to extend their dominant hand from an upright standing position while touching the top of an elastic stick fixed at a dominant acromion height on the wall. This test does not require a large space, and the reach distance is easily measured. 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. The 10-m walk test with maximum effort was used to evaluate walking ability. These tests were performed in one trial.

2.4. ADL

The ADL survey was used in this study; this survey was developed to confirm whether the elderly can safely participate in a physical fitness test by the Ministry of Education, Culture, Sports, Science and Technology of Japan. This survey consists of the following four domains: locomotion (walking, running, jumping across a ditch, ascending and descending stairs, and conveyor belt), posture change (sitting up and standing up from the floor), stability (one-leg standing with eyes open, standing in a bus or a train, and dressing while standing), and manipulation (buttoning a shirt and placing a Japanese mattress into and removing it out of a closet). The degree of the achievement of ADLs required for independent life is evaluated using 12 items [19,20]. Each item consisted of three different difficulty levels, with subjects selecting the appropriate level for each ADL item. The total score of 12 items was used as an index of ADL ability. In addition, the elderly with a higher ADL score were judged to be superior in ADL ability.

2.5. Fall risk

Demura’s fall risk assessment [21] was used in this study. This consisted of 50 items representing the following 5 risk factors: symptoms of falling (3 items), disease and physical symptoms (13 items), environment (4 items), behavior and character (eight items), and physical function (22 items). All responses were rated on a dichotomous scale (Yes or No), with one point being assigned to each response that fell into the high-risk category. The scores for each risk factor and the total fall risk were used as evaluation parameters. In addition, a higher score was interpreted as having higher fall risk.

2.6. Statistical Analysis

Mean differences between PG and IG were examined using the unpaired t-test for each parameter. The size of the mean difference was examined by an effect-size (ES). A difference in fall experiences during the past year was examined using the chi-square frequency test (χ^2 test). The significance level in this study was set at $p < 0.05$, which was adjusted using Bonferroni’s method.

3. Results

Table 1 shows the basic statistics of age, height, and body weight in PG and IG, and the test results between their means. No significant difference was found between both groups for all parameters. Table 2 shows the basic statistics of leg strength, balance ability, walking ability, and ADL in both groups, and the test results between their means. One-leg standing with eyes open, 10-m walking, and ADL were significantly superior in PG compared with IG, and their ESs were moderate (0.49–0.68). Table 3 shows the basic statistics of the number of fall experience during the past year and their rates and the test results. The number of fall experience was significantly fewer in PG than in IG. Table 4 shows the basic statistics of fall risk factor scores in both groups, and the test results between their means. No significant difference was found between both groups for all parameters.

Table 1. Basic statistics of age, height and body weight in PG and IG, and the test results between their means

	PG (n = 123)				IG (n = 20)				t	p
	M	SD	MAX	MIN	M	SD	MAX	MIN		
Age	76.6	5.5	89	62	79.2	6.1	88	66	1.90	0.06
Height	147.9	5.1	160.6	134.9	146.3	5.7	157.6	137.5	1.01	0.32
Body weight	49.2	7.3	74.1	32.4	50.4	7.3	66.5	38.3	0.66	0.51

Table 2. Basic statistics of leg strength, balance ability, walking ability, and ADL in PG and IG, and the test results between their means

	PG(n = 123)				IG(n = 20)				t	p	ES
	M	SD	MAX	MIN	M	SD	MAX	MIN			
Toe finger strength	4.67	2.18	13.25	1.10	4.19	1.56	6.95	1.45	0.77	0.44	0.19
Hip flexion strength	12.07	3.45	25.65	4.07	12.05	4.03	20.25	6.60	0.05	0.96	0.01
Knee extension strength	6.67	2.31	15.62	2.50	6.06	2.04	13.40	3.19	1.07	0.29	0.26
One leg standing	41.51	41.40	120	1.72	21.31	26.45	92.3	2.10	2.62*	0.01	0.63
Functional Reach	31.88	5.76	53.4	19.4	30.71	7.20	42.0	12.8	0.73	0.47	0.18
10m waking	6.22	1.41	15.2	4.10	7.55	1.92	12.1	4.23	2.79*	0.01	0.68
ADL	26.1	4.85	36	15	23.6	4.76	31	14	2.02*	0.046	0.49

*: $p < 0.05$.

Table 3. Basic statistics of the number of fall experiences during the past year and their rates in PG and IG and the test results

	PG(n = 123)		IG(n = 20)		χ^2	p
	n	%	n	%		
Number of fall experiences	26	(21.1%)	9	(45.0%)	4.87*	0.03

*: $p < 0.05$.

Table 4. Basic statistics of fall risk factor scores in PG and IG, and the test results between their means

	PG(n = 123)				IG(n = 20)				t	p
	M	SD	MAX	MIN	M	SD	MAX	MIN		
Symptoms of falling	0.7	0.8	3	0	1.1	0.8	3	0	1.46	0.15
Disease and physical symptoms	3.2	1.9	8	0	4.1	1.9	9	1	1.72	0.09
Environment	1.1	0.9	3	0	1.0	0.8	3	0	0.50	0.62
Behavior and character	3.8	1.2	7	1	4.1	1.2	6	2	0.87	0.39
Physical function	8.4	4.4	19	0	11.0	4.6	19	3	2.18	0.03

$\alpha' < 0.05/5 = 0.01$.

4. Discussion

Noguchi et al. [17] examined the stability of the posture on an unstable stool leaning in all directions using young males. This test is very difficult, and there is also the occurrence of risk for the elderly. Hence, an unstable stool leaning only in the backward and forward directions [16] was used to evaluate the elderly's balance ability in this study. Among all subjects, 14.8% of the elderly (IG) could not perform the balance board test for 20 s in successive two trials. They were judged to be inferior in passive balance ability compared with the elderly (PG) who could perform it two times.

Leg strength of more than a certain level is essential for maintaining a stable posture in old age. The decrease is related closely to that in balance ability [22]. Hence, it is hypothesized that IG is inferior in leg strength compared with PG. However, an insignificant difference was found in leg strength between both groups. All the elderly in this study could achieve ADL independently. Hence, it is considered that they had leg strength that was over a certain level. In addition, the above test demands subjects to maintain a stable posture using the whole body, including the arms. Hence, balance ability may greatly affect the performance of this test rather than leg strength. On the other hand, a relationship has been reported between leg strength and fall [23]. Hence, we selected hip flexion, knee extension, and toe flexion strength in this study to evaluate leg strength. However, antigravity muscle such as biceps femoris and soleus muscles are also involved in maintaining the standing posture [24]. It will be necessary to examine the effect of the above muscles in a future study.

The one-leg standing posture is sometimes used in daily living activities [25]. The somatic sensation system contributes greatly to the maintenance of a stable posture during one-leg standing [7]. Melzer et al. [26] reported that the elderly with fall experience show large sway center of foot pressure than the elderly without it. In short, it is considered that the elderly with fall experience have large body sway during one-leg standing, and that their posture becomes fairly unstable [27]. Thus, one-leg standing with eyes open has been used as a test to evaluate static balance ability. From the present results, it is judged that the elderly with inferior passive dynamic balance ability are also inferior in static balance ability.

Functional reach has been developed as a test to assess dynamic balance ability [9,10]. The present results showed no significant difference for this test between both groups. Ankle joints are strongly related to both the tests of functional reach and balance board [28]. In the former test, ankle joints require large flexion because the body gradually leans forward. In the latter test, the body receives continuous involuntary stimulation, and ankle joints are forced to undergo quick repetition of flexion and extension because an unstable stool leans sharply in the backward and forward directions. In short, a use way of ankle joints is considerably different between both tests. Hence, it is considered that even among IG, some persons could perform the functional reach test well.

Takeshima and Rogers [6] reported that dynamic balance ability can be assessed by the walking test because the center of gravity of the body moves largely in the traveling direction during walking. Hence, it is hypothesized that the 10-m walk time with maximum effort was slower in IG than that in PG. In the present results, this hypothesis was adopted. Various physical fitness factors are related to the elderly's walking speed or time [7]. Particularly, leg strength contributes largely to the walking speed [29]. However, as already stated, leg strength of both groups did not differ. It is considered that regardless of superior or inferior leg strength, elderly subjects with inferior balance ability as measured in this study are also inferior in ability to walk quickly.

The present ADL survey, which consists of the four domains of locomotion, manipulation, stability and posture change, synthetically evaluated the degree of achievement of various daily living activities by the elderly [19,20]. Demura et al. [19] provided the following definitions: persons with more than 24 points have a high physical fitness level, those with 12–24 points have a physical fitness level less than the average and find it somewhat difficult to achieve daily living activities, and those with less than 12 point have difficulty in the achievement of many daily living activities. The ADL score was significantly higher in PG (26.1) compared with IG (23.6) in this study. It is judged that IG is inferior in the achievement of ADL. However, elderly subjects with a high physical fitness level are from IG, because the IG's average score (23.6) is similar to those with a high physical fitness level (24). Hence, it is considered that even many elderly individuals who find it difficult to perform the balance board test can sufficiently achieve independent daily life.

Fall in the elderly is caused by various causes [23]. IG (45.0%) had more fall experience during the past year compared with PG (21.1%). Tinetti and Williams [3] and Mary and Tinetti [4] reported that a decrease in leg strength, balance ability, walking ability, achievement ability of ADL, etc., is related to fall. IG may often fall compared with PG due to being inferior in the above abilities expect for leg strength.

Demura's fall risk assessment [21] was used in this study. This consists of the following five risk factors: "symptoms of falling," "disease and physical symptoms," "environment," "behavior and character," and "physical function." The present results showed that significant differences were not found for all parameters between PG and IG. However, a score of the symptoms of falling factor in IG was 1.1 point (see Table 4). Demura et al. [30] reported that the cut-off score in this factor for subjects with high fall risk is 1.0 point. No significant difference was found between both groups; however, it is suggested that IG has high possibility for fall experience in the future. More accurate fall prediction may be possible using the balance board test in addition to the above fall risk survey.

5. Conclusion

The female elderly who cannot perform the present balance board test have more fall experience and are inferior in one-leg standing with open eyes, walking ability, and ADL compared with the elderly who can perform it despite having similar static leg strength.

Acknowledgement

Research funds were not provided by any institution.

Conflict of Interest Statement

None.

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