Research Paper: The Effect of Training on Stable and Unstable Surfaces on Static Balance in Healthy Elderly

Zohreh Afsharmand[1*], Mahdiyeh Akoochakian[1], Hasan Daneshmandi[2], Yahya Sokhanguei[3]

1. Department of Sport Sciences, Kish International Campus, University of Tehran, Kish, Iran.
2. Department of Physical Education & Sport Sciences, Faculty of Sport Science and Physical Education, University of Guilan, Rasht, Iran.
4. Department of Physiotherapy, University of social Welfare and Rehabilitation Sciences, Tehran, Iran.

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ABSTRACT

Purpose: Static balance decrease with aging. Exercise program has significant effects on improving balance. However, the most effective method on improving balance in elderly remains undiscovered. Therefore, the present study investigated the effect of training on the stable and unstable surfaces on the static balance in elderly.

Methods: This was a clinical randomized trial with a pre-test post-test design. A total of 75 elderly women were studied. The samples were assigned into 4 different exercise groups and a control group. Biodex Balance equilibrium was used to record static balance and Berg Balance Scale (BBS) was applied to record functional balance. Data were analyzed using one-way Analysis of Variance at the significance level of P<0.05.

Results: The total balance, anterior-posterior and medio-lateral balance scores significantly decreased in the training groups after performing the exercise program (P=0.00). After conducting the exercise program, balance scores differently decreased in different groups (P<0.01).

Conclusion: The exercise program improved the BBS, total balance, anterior-posterior, and mediolateral balance scores in the elderly subjects. The proprioceptive system function decreases with aging; thus, exercising on an unstable surface can challenge the proprioceptive system and increase proprioceptive function in elderly. The obtained results revealed that exercising on foam and sand improve the function of this system, due to the involvement of proprioceptive system. Thus, the increased involvement of proprioceptive system in balance, may improve balance on unstable surfaces, compared to hard ones.

*** Corresponding Author:**
Zohreh Afsharmand, PhD. Candidate
Address: *Department of Sport Sciences, Kish International Campus, University of Tehran, Kish, Iran.*
Phone: *+98 (912) 4631442*
E-mail: *afsharmand_ro@yahoo.com*

Highlights

- The balance in the exercises group improved compared to the control group.
- The balance improved differently in exercise groups.
- The exercise on foam and sand may improve balance better than exercise on hard surfaces in the elderly.

Plain Language Summary

In this study 75 elderly woman were divided into 4 different exercise groups and one control group. Biodex balance system was used to record static balance, and Berg Balance Scale (BBS) was used to record functional balance. The results indicated that total balance improved significantly in exercise groups on sand and foam more than exercise on stable surface. Exercise on these unstable surface involve the proprioceptive system and create a safe place for elderly to do exercise without the risk of falling

1. Introduction

Reduced balance is common with aging [1]. Balance and inadequate mobility threaten independence in everyday life activities and may increase the risk of falling [2]. Falling may cause bone fractures and consequently, reduces the quality of life. Increased disabilities impose higher healthcare economic burden to societies [3]. The harmful consequences of falls have caused the scholars to explore effective interventions to control the associated risk factors of falling in elderly. Almost 40% of people over the age of 65 years, experience falls at least once per year. About 10-20% of falls lead to hospitalization. The high prevalence of falls is because of risk factors like the decreased postural balance due to aging and strength loss [4]. A training program aimed at improving the strength of the lower limb muscles can improve balance performance [5], and consequently, reduce the risk of falling [6].

Postural control is the result of relationship between the function of proprioception system and sensory-motor system. Proprioception system is an important source of sensory information feedback and prevents the loss of balance during stance [7]. Balance performance in elderly is sensitive to the feedbacks of proprioception system. The accuracy of proprioception sense is low in elderly [8]; because of poor ankle and knee proprioception, they experience balance weakness [9]. The weakness in the proprioception system in elderly is associated with higher balance weakness in anterior–posterior direction [10], as well as a less reduced balance in the lateral direction during stance [11] .Physical activity can enhance the proprioception sense in elderly. The knee joint proprioception is higher in active elderlies, compared to their inactive counterparts [12]. Improved proprioception in elderly may depend on the type of exercise [13, 14]. For example, Tai Chi exercise can increase the proprioception and motion detection threshold of joints in elderly [14].

In another study, proprioception sense training in elderly golfers led to improved motion precision and balance control [13]. Hamed et al. suggested that exercising on unstable surfaces increases ankle strength and improves sensory information processing in sudden perturbations [15]. According to Azarpaikan and Taheri Torbati, somatosensory and neurofeedback training could improve the dynamic and static balance of healthy elderly [16]. Chatutain et al. reported that walking exercises could improve the ankle proprioception and increase balance in elderly women [17].

Borysiuk et al. indicated that performing balance exercise on a 10-cm foam pad (unstable surface) could increase the limits of stability and coactivation of muscles in elderly women [18]. In general, exercise improves balance in elderly. Balance training for elderly should include strength and balance exercises [19, 20]. Balance improvement programs should be accompanied by moderate to severe balance challenges. By reducing the base of support and weight transfer, a moderate to severe challenge can be created for balance. Its intensity should be increased according to the person's progress [20].

With aging, the proprioception of the ankle and knee joints is weakened, which leads to a reduction in the balance of elderly [9]. Meanwhile, the improvement of proprioceptive system function can promote elderly's balance performance. Exercises that higher challenge this system may possibly better improve this system and balance in elderly. Therefore, the comparison of various training methods with different involvement levels of the proprioceptive system can demonstrate their extent of effectiveness.

To our knowledge, there is no study that has investigated the effect of different training methods on the improvement of balance in elderly. Therefore, the present study attempted to use 4 training methods, including exercising on 6- and 9-cm foam mats, exercising on sand and exercising on the ground to examine their effects on the static balance of elderly. It was hypothesized that these exercises have no significant effects on the improvement of balance in this age group.

2. Materials and Methods

This was a quasi-experimental study (cross-sectional) with a pretest-posttest design. The study samples were 75 elderly women aged 60-80 years who were selected using convenience and purposive sampling techniques. The subjects were selected from retired teachers after coordination with the Department of Education in district 1 of Alborz Province, Iran. Inclusion criteria were the age of 60-80 years; no history of cardiovascular and respiratory problems and fractures in the last 6 months; the ability to live independently; no use of walking aids; no acute and chronic bio-psychological disorders; the lack of performing regular exercises; the ability to regularly participate in training sessions; the ability to follow simple commands; and obtaining a Mini-Mental State Examination (MMSE) score of >24. Exclusion criteria were having a history of osteoporosis, fractures or lower extremity surgery; a history of neuromuscular disorders; whiplash injury, neck injury, or neck pain; unstable angina or uncontrolled cardiorespiratory problems; and the use of medications such as benzodiazepines, antidepressants or hypnotics that can affect balance.

After selecting the study participants, the research purpose and steps were explained to all subjects, and a written informed consent form was obtained from them. Then, they were randomly assigned into 4 experimental groups and one control group. To assess the balance abilities of the subjects, Berg Balance Scale (BBS) was used. For objective balance assessment, the Biodex Balance System (Biodex Inc., Shirley, New York) was employed. BBS has 14 items and measures the ability of individuals to maintain balance while performing daily tasks such as sitting and single leg stance. Its rating is based on a 5-point scale ranging from 0-4, where “0” demonstrates the lowest function level, and “4” indicates that the individual is functionally independent in performing daily living tasks.

The total attainable score is 56 which is calculated by summing up the points of different scales. Higher scores indicate better ability to keep balance. The effectiveness of intervention is evaluated according to the functional balance [21]. BBS was considered, because it is mainly used in elderly [22]. The reliability of each scale and the reliability between the scales have been reported as 98% and 99%, respectively. Moreover, its internal consistency has a Cronbach’s alpha of 96% and is considered as an effective tool for measuring the functional balance [23]. Biodex Balance System was used to assess antero-posterior, mediolateral and total balance indices. The test–retest reliability [24] and validity [25] of the results obtained from this device have been previously reported.

For testing, the subject was requested to stand barefoot on the surface of the Biodex Balance System with the hands folded on chest. The device was initially locked and the subject was looking forward. The angle of feet on the device plate was recorded for the uniformity of the test, in the post-test phase. After turning on the device and recording demographic characteristics, the subject was allowed to recover balance and place the feet in a position that would make it easier to regain balance. Then, the position of feet and their angle on the plate were recorded. The subjects’ balance was recorded with eyes open and closed for 20 s. To prevent the subjects from falling and injury, the examiner stood behind them. Eventually, their anteroposterior, mediatorial and total balance indices were recorded.

Exercise protocol

Impaired static and dynamic balance may disturb postural control and walking; thus, it is one of the indicators of aging. The applied exercises were designed to prevent the deterioration of functional balance weakness and falling, with a focus on balance needs, maintaining postural control, and dynamic activities [26]. The exercise protocol was performed with the necessary precautions and assuring of its safety. Moreover, the study participants were allowed to discontinue the exercise program as desired. All subjects performed a selected exercise program for 8 weeks, 3 sessions per week that each lasted for 1 h and 30 min. The selected exercise program included the movements adapted from the 3 recommended physical activities to improve balance in elderly [27, 28].

Table 1. Corrective exercises protocol

Exercise	Weeks 1-2	Weeks 3-5	Weeks 6-8
Rest time between sets	3 min	2 min	1 min
Warm up	10 min	5 min	5 min
Heel-to-toe exercise	8 reps*	10 reps	15 reps
Run in place	10 reps	15 reps	20 reps
Draw alphabets with the right leg and left foot	5 capital letters in the air	8 capital letters on a towel	10 capital letters on a towel
Sit down and get up from a chair	4 reps	6 reps	8 reps
Move the right and left foot forward, backward and sideways	8 reps	10 reps	15 reps
Raise arms	8 reps for 5 sec	10 reps for 8 sec	15 reps for 10 sec
Stand on the right and left foot	8 reps for 5 sec	10 reps for 8 sec	15 reps for 10 sec
Normal walking in a straight line, overlap gait, and tandem gait	An 8-m normal walk in a straight line	A 10-m overlap gait	A 10-m tandem gait
Cool down	10 min	5 min	5 min

*Reps: repetitions

PHYSICAL TREATMENTS

The three experimental groups performed exercises on unstable surfaces; one on a 6-cm foam mat, the second on a 9-cm foam mat, and the third group on sand. One experimental group performed the exercises on a stable surface (ground). The control group received no intervention. In total, the training program included 24 sessions and divided into three steps, as follows: 1. a 5- to 10-min warm up by walking and stretching movements; 2. Physical activity for 45-60 min (Table 1); and 3. a 5- to 10-min cool down.

The statistical analysis was performed after examining the normality of data distribution using the Kolmogorov–Smirnov test. After confirming the normal distribution of data, one-way Analysis of Variance (ANOVA) and repeated measures ANOVA were employed in SPSS. The significance level was set at P<0.05.

3. Results

The demographic characteristics of study participants are presented in Table 2. There was no significant difference between exercise and control groups (P>0.05). Between-group comparisons are listed in Table 3. Table 3 reveals no significant difference between the study groups in the pretest phase in terms of anteroposterior, mediolateral and total balance indices (P>0.05). Exercise factor had a significant effect on the balance of subjects (P<0.05). In the experimental groups, total balance and balance in anteroposterior and mediolateral directions significantly reduced after conducting the intervention (Table 3). The vision had a significant effect on total balance and anteroposterior balance (P<0.05); however, no significant effect was detected on mediolateral balance. The mean scores of total balance and anteroposterior balance while testing with eyes closed indicated higher values, compared to surface standing tests under “eyes open” conditions (Table 4).

A significant interaction was also observed between balance and exercise type (P<0.001), i.e. after conducting the intervention, balance level reduced differently in groups. Table 5 presents pretest and posttest mean score differences in anteroposterior, mediolateral and total balance indices. As demonstrated, sand exercise caused the most improvement in anteroposterior and total balance. Mediolateral balance significantly improved by performing exercise on a 10-cm foam mat. The least changes were observed in the group where participants performed exercises on sand. Moreover, the difference in the mean score of balance was not significant in the controls.

According to the obtained results, BBS scores significantly differed before and after the intervention (Table 6). It was significantly improved at the post-test (P<0.001). There was a significant interaction between group and exercise factors (P=0.002); i.e. the mean score of functional balance significantly increased after conducting the intervention in different groups; the mean difference score was higher after performing exercise on a 10-cm foam mat (7.58). ANOVA results for BBS are shown in Table 7.

Table 2. The demographic characteristics of study participants and one-way ANOVA results

Variable	Mean±SD					F	Sig.
	The Experimental Group (Exercise on a 6-cm Foam Mat)	The Experimental Goup (Exercise on a 10-cm Foam Mat)	The Experimental Group (Exercise on Sand)	The Experimental Group (Exercise on the Ground)	Control Group		
Age (yr)	63.00±5.88	63.63±2.29	63.33±5.74	63.93±3.81	63.27±5.19	0.036	0.99
Height (cm)	156.42±5.99	156.55±6.35	153.67±2.16	157.60±4.64	156.62±5.09	1.337	0.26
Weight (kg)	66.82±9.51	73.75±12.51	67.39±7.68	69.48±10.28	72.38±13.06	1.072	0.37
BMI (kg/m^2)	27.35±3.82	30.22±5.67	28.51±2.90	25.37±7.07	29.65±6.10	11.89	0.46
MMSE	26.33±2.67	26.00±1.84	26.40±1.48	25.86±1.68	26.80±1.82	0.54	0.70

PHYSICAL TREATMENTS

Table 3. ANOVA results for examining the effect of exercise on balance

Variables	Pre-test	Post-test	Sum of Squares	df	Mean Squared	F	Sig.	β
Total balance	2.94±0.09	2.22±0.08	35.33	1	35.53	162.46	0.00	0.72
Anteroposterior balance	2.21±0.08	1.65±0.07	21.40	1	21.40	163.15	0.00	0.72
Mediolateral balance	1.59±0.09	1.13±0.06	13.68	1	13.68	74.23	0.00	0.54

PHYSICAL TREATMENTS

Table 4. ANOVA results for examining the effect of vision on balance

Variables	Testing With Eyes Open	Testing With Eyes Closed	Sum of Squares	df	Mean Squared	F	Sig.	β
Total balance	2.49±0.10	2.67±0.08	2.09	1	2.09	7.99	0.01	0.11
Anteroposterior balance	1.83±0.08	2.02±0.08	2.35	1	2.35	9.77	0.00	0.13
Mediolateral balance	1.35±0.09	1.37±0.07	0.01	1	0.01	0.02	0.88	0.00

PHYSICAL TREATMENTS

4. Discussion

This study evaluated the effects of 4 different exercise methods on the static balance of elderly women. After performing all exercises, the total balance scores of subjects and their balance in anteroposterior and mediolateral directions significantly improved. The BBS scores of subjects also significantly increased. The most improvement was observed among those who performed exercises on sand and on a 10-cm foam mat. The obtained

Table 5. ANOVA results for examining the effect of exercise type on balance

Variables	Experimental Group				Control Group	Sum of Squares	df	Mean Squared	F	Sig.	β
	Exercise on a 10-cm Foam Mat)	Exercise on a 6-cm Foam Mat)	Exercise on Sand)	Exercise on the Ground							
Total balance	-0.96	-0.74	-1.05	-0.90	0.00	10.57	4	2.64	12.08	0.00	0.43
Anteroposterior balance	-0.65	-0.069	-0.93	-0.59	0.01	7.23	4	1.81	13.77	0.00	0.47
Mediolateral balance	-0.90	-0.34	-0.63	-0.43	0.03	6.5	4	1.62	8.82	0.00	0.36

PHYSICAL TREATMENTS

Table 6. The Mean±SD of the BBS before and after intervention

Groups	Mean±SD		Mean Difference
	Pre-test	Post-test	
Tested on a 10-cm mat	48.00±3.79	55.58±1.51	7.58
Tested on a 6-cm mat	49.45±6.11	54.59±4.87	5.14
Tested on sand	49.80±3.38	54.00±2.67	4.20
Tested on the ground	51.60±2.32	55.83±4.30	4.23
Control	48.33±6.10	48.93±6.08	0.60

PHYSICAL TREATMENTS

Table 7. ANOVA results for BBS

Source	Sum of Squares	df	Mean Squared	F	Sig.	β
Exercise	1264.41	1	1264.41	69.97	0.00	0.53
Group*exercise	341.33	4	85.33	4.72	0.02	0.23
Error	1138.39	63	18.07	-	-	-

PHYSICAL TREATMENTS

results also reported that vision had a significant effect on the balance of elderly women. This indicates that their balance is largely dependent on visual contribution. Furthermore, in case of surface standing with closed eyes, their static balance significantly decreases (static balance is decreased with increasing deviation). This is consistent with the results of Lord et al. [11], Shigematsu et al. [29], and Bird and colleagues [30].

Lord et al. examined the balance of 156 elderly men and women with eyes open and closed. They observed that with eyes closed, they experienced falls; moreover, the elimination of vision factor led to the adoption of a gait strategy in elderly. Visual motion can create information for the body's movements in relation to the surrounding world, and can improve the right posture. In quiet standing, body sways around the ankle joint and as a result, motion effects changes. The central nervous system interprets the movements in the visual field. In daily activities, visual information (as a feedback source) is very effective in controlling the balance. It has been reported that postural control with closed eyes aggravates by 30%, compared to standing [10, 31].

The obtained data revealed that balance significantly improved in anteroposterior direction among all experimental groups after the intervention. This is in line with the findings of Bullo et al. Newell et al., Gardner et al., Weerdesteyn et al. and Mokhtari et al. [32-36]; however, it is in contrast with Heiden and Lajoie and Narita et al. studies [37, 38]. Newell et al. conducted stability exercises, balance exercises, and lower extremity strength exercises in elderly men and women. They found that anteroposterior sway decreased after the intervention, but the controls showed no improvement. Gardner et al. examined the effect of Greek rhythmic aerobic exercises on 28 elderly people for 8 weeks. They reported significantly decreased falls in an anteroposterior direction.

Mokhtari et al. conducted a 12-week Pilates exercises program. They reported an improvement in anteroposterior balance. On the other hand, Heiden and Lajoie reported that their balance training program had no effect on anteroposterior sway in elderly. Perhaps this inconsistency is because of the low number and duration of sessions (16 sessions for 30 min) or due to the small sample size (n=9). Narita et al. concluded the dynamic balance significantly improved in elderly women after conducting a balance exercise program; however, their static balance remained unchanged.

The current study also demonstrated a significant improvement in the mediolateral balance of all experimental groups after performing the training program. This is consistent with the findings of Bullo et al. Mokhtari et al. and Heiden and Lajoie [32, 36, 37]. Heiden and Lajoie reported the balance training program could improve static balance in mediolateral direction. Gardner et al.

[34] argued that the dynamic balance of elderly people in mediolateral direction improved after rhythmic aerobic exercises.

Bird et al. studied 32 elderly people [30]. They concluded that Pilates training intervention could improve mediolateral sway range while standing on a foam cushion with eyes closed. According to Shigematsu et al. elderly women performed aerobic exercises for 12 weeks; the exercise groups showed significantly greater balance, compared to the controls [29, 38]. The current study also suggested a significant improvement in BBS in all experimental groups after performing exercises; this data is consistent with the results of Madureira et al., Eyigor et al., and Johnson and associates [39-41]. Their study on elderly people also revealed that after performing the selected training programs, BBS significantly improved in the subjects.

In this study, among examined exercises, those performed on sand and on a 10-cm foam mat had greater effects on improving the BBS as well as anteroposterior, mediolateral, and total balance scores. Structural and functional reduction in the somatosensory system are associated with aging and postural instability. Proprioception sense provides information about the position and motion of joints and tendons. The data of the lower extremities are the most important confounding factors of balance. The proprioceptive threshold is significantly lower than the visual and vestibular thresholds in perceiving the speed of pressure under the feet [7].

Many researchers have suggested that aging leads to changes in muscle spindles. Morphological changes such as increased capsule thickness and reduced number of intrafusal fibers [42] may be the cause of weakness in the sensitivity of dynamic and static muscular spindles, associated with aging [43]. Evidence suggests that age-related changes in the muscular spindle occur more often in the distal muscles [44]. Postural control may relate to the proper use and function of the sensory afferents as well as the muscular strength of lower limbs. Physical activity and proprioceptive exercises can limit dynamic postural control in elderly people. This process is done by increasing proprioceptive system contribution, followed by enhanced muscle strength [45].

In the present study, to increase the proprioceptive system contribution, the training program was conducted on foam mats and sand. The intrinsic instability in these exercises, in addition to strengthening the muscular system, can increase the contribution of the proprioceptive system in transferring data after the training program. Thus, these exercises provide a better improvement for elderly, compared to the traditional exercises performed on the ground.

The training program improved the BBS and anteroposterior, mediolateral, and total balance scores in the studied elderly. Aging reduces the function of proprioceptive system; therefore, exercising on unstable surfaces can increase the proprioceptive system function. Performing exercises on foam mats and sand cause greater improvement in elderly's balance, compared to those performed on stable surfaces; this is due to the increased involvement of proprioceptive system.

A limitation of the current study was that due to the financial constraints, it was not possible to provide a nutrition program along with a training program for exercise groups.

Ethical Considerations

Compliance with ethical guidelines

After selecting the study participants, the research purpose and steps were explained to all subjects, and a written informed consent form was obtained from them.

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Authors' contributions

Conceptualization: Zohreh Afsharmand, Mahdieh Akoochakian, Hasan Daneshmandi; Methodology: Zohreh Afsharmand, Mahdieh Akoochakian, Yahya Sokhnguei; Investigation, writing-review & editing: All authors; Resources: Zohreh Afsharmand, Yahya Sokhnguei; and Supervising: Mahdieh Akoochakian, Hasan Daneshmandi, Yahya Sokhnguei.

Conflict of interest

The authors declared no conflict of interest.

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