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Original Article

Comparisons of the effects of a foam pad, mung bean bag, and plastic bead bag on postural stability disturbance in healthy young adults

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Abstract. [Purpose] The aim of the present study was to compare the effects of unstable support surfaces, i.e. foam pad, mung bean bag, and plastic bead bag, on postural stability disturbance. [Subjects and Methods] Twenty-two healthy young adults (11 male and 11 female; aged 21.09 ± 1.44 years; BMI 20.40 ± 1.40 kg/m^2) participated in the study. The Balance Master™ was used to evaluate the limit of stability and the unilateral stance performance. Each participant was assessed while standing on the following surfaces: 1) a firm surface, 2) a foam pad, 3) a mung bean bag, and 4) a plastic bead bag. The order of surfaces was randomly assigned. [Results] The mung bean bag and plastic bead bag showed greater disturbances in limit of stability and unilateral stance than the foam pad. There was no significant difference in postural stability disturbance between the mung bean bag and plastic bead bag. [Conclusion] These results suggested that both the mung bean bag and plastic bead bag could be used as a low-cost tool for balance assessment instead of a foam pad in healthy young adults.

Key words: Postural balance, Foam pad, Unstable surface

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INTRODUCTION

Postural stability or balance is the basis of numerous activities in daily living such as sitting, sit-to-stand, standing, reaching, walking, and stair climbing. Balance impairment is strongly associated with increased risk of fall, trauma to body parts, and functional limitations[1)]. To control postural stability, a complex continuous integration of sensory information, i.e. vestibular, visual, proprioceptive, and mechanoreceptive information, is required[2)]. The central nervous system processes this information to build a body schema in relation to external environments and to produce appropriate motor responses to maintain the body's center of gravity (COG) within the base of support (BOS). In the meantime, the central nervous system also receives feedback from sensory receptors used to perceive the error between motor commands and responses as well as to adjust motor planning for further appropriate reactions[3)]. In order to challenge postural stability for assessments and trainings, constraint or alteration of these sensations can be used (e.g., with head movement, eyes closed, a narrow BOS, altered the proprioceptive feedback with unstable support surfaces).

There are several types of unstable support surfaces commercially available in the market. One of the most generally used types of equipment to challenge postural stability is the foam pad[4, 5)]. The foam surface extremely alters proprioceptive and mechanoreceptive information from the feet. Accordingly, the ability to detect body orientation and to exert accurate corrective postural responses is reduced[6)]. Several previous studies demonstrated that body movement increased significantly while subjects stood on a foam surface as compared to a firm surface[7–9)]. In addition, balance training performed on a foam surface significantly improved postural stability[10)]. These results may be, in part, due to an increase in afferent input from

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skin mechanoreceptors and proprioceptors in the muscles and joint caused by postural sway while standing on unstable surfaces[11, 12]. Although the foam pad can disturb balance and can be used for balance training, the commercially available foam pads are somehow expensive and rarely available, especially in rural areas. Therefore, we searched for other materials to use as unstable support surfaces to assess balance. Previous studies revealed that a nodular material altered the response of somatosensory receptors in the soles of feet[13]. Thus, this study was designed to investigate the efficacy of two nodular materials, i.e., a mung bean and a high-density polyethylene (HDPE) plastic bead, in causing postural stability disturbance. The mung bean is an agricultural product that is cheap and easily available, whereas the HDPE plastic bead is an industrial product that is cheap and has long durability. We hypothesized that standing on a mung bean or HDPE plastic bead bag, as well as standing on a foam pad, could disturb static and dynamic balance.

SUBJECTS AND METHODS

Twenty-two healthy young adults (11 males and 11 females; aged 21.09 ± 1.44 years; BMI 20.40 ± 1.40 kg/m^2; right/left dominant stance leg = 3/19) were recruited for this study (Table 1). The inclusion criteria were as follows: normal visual acuity (the participant could wear eyeglasses or contact lens), ability to stand in a bipedal position with the eyes closed without help for 20 seconds, ability to stand on one leg for 30 seconds, no history of musculoskeletal or neurological disorders, no history of back or lower limb operation, normal muscle power of lower limbs, and no use of medicine or alcohol within 48 hours before the test. The exclusion criteria was occurrence of any lower-limb injury during participation in the study.

The protocol of this study was approved by the Ethics Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University (Project No. 077.1/57). All participants gave written informed consent prior to participating in this study.

Participants' balance abilities were measured using a NeuroCom Balance Master™ (NeuroCom, Clackamas, OR, USA). A within-subject repeated measures design was used. Each participant's balance ability was measured while standing on various supporting surfaces: a firm surface, foam pad, mung bean bag, and HDPE plastic bead bag. Two balance measurements were performed—the unilateral stance (US) test and limit of stability (LOS) test—to investigate the efficacies in causing static and dynamic postural stability disturbance of the 4 different surfaces, respectively. To counterbalance order effects, the order of support surfaces was randomly assigned. Participants also had a 5-minute break between each surface in each measurement.

Three bags were made for inserting the foam pad, mung beans and HDPE plastic beads. The size of the bag was 0.47 × 0.52 × 0.10 m (width × length × height), which produced the volume of 0.024 m^3. The masses of the inserted foam pad, mung beans and HDPE plastic beads were 2.2 kg, 16.3 kg, and 16.1 kg, respectively. The bags consisted of two layers, which were made from different types of fabrics. The inner layer was made by calico fabrics for inserting mung beans, plastic beads, or the foam pad. The outer layer was made of a stretchable fabric that allowed for weight bearing. A polypropylene board was used as a frame to limit spreading of the inserted material.

For the US test, participants stood on one leg with the arms crossed for 10 seconds under the following conditions: standing on the dominant leg with the eyes closed, standing on the dominant leg with the eyes open, standing on the nondominant leg with the eyes closed, and standing on the nondominant leg with the eyes open. Each condition was performed 3 times. The position for lifting of the lower limb was 90° knee flexion and 90° hip flexion. The dominant stance leg of participants was determined by asking them which leg they would use to kick a ball. The ipsilateral and contralateral legs based in the answer given were considered the nondominant and dominant stance legs, respectively. The sway velocity, the average speed of the center of gravity movement, was recorded.

In the LOS test, the farthest a participant could lean in 8 directions (i.e., forward, right-forward, right, right-backward, backward, left-backward, left, and left-forward) without stepping, reaching for assistance, or losing his/her balance was measured. The participant was allowed up to 8 seconds to complete the test in each direction. The results for COG movement velocity (the average speed of the COG movement), maximum excursion (the farthest range a participant could lean in the first try), end-point excursion (the farthest range a participant could lean without losing his/her balance) and direction control (a comparison of the amount of movement in direction toward the target and the amount of movement in direction away from target) were recorded.

All results are shown as the mean ± standard deviation (SD). Statistical analysis was performed using GraphPad Prism version 6.0 (GraphPad Software, La Jolla, CA, USA). Two-way repeated ANOVA followed by Bonferroni post hoc analysis was used to determine if any significant differences were present among surfaces (firm surface, foam surface, mung bean bag, and HDPE plastic bead bag) and directions in the LOS test or among surfaces and conditions (eyes open or eyes closed) in the US test. The statistical significance level was set at a p-value equal 0.05.

RESULTS

The US was used to evaluate the ability of different support surfaces to cause static postural stability disturbance. Table 2 shows the sway velocity (SV) from the US test. As compared with the firm surface, there was a significant increase in SV when subjects stood on the foam surface, mung bean bag, and HDPE plastic bead bag in the eyes-closed condition. Interestingly, both the mung bean bag and HDPE plastic bead bag demonstrated greater SVs in the eyes-open condition as compared with the foam surface. The same pattern of results was found for both the dominant and nondominant stance legs.

The LOS was used to investigate the ability of different support surfaces to cause dynamic postural stability disturbance. Table 3 compares the COG movement velocity (MVL), endpoint excursion (EPE), maximum excursion (MXE), and directional control (DCL) from the LOS test when subjects stood on the firm surface, foam surface, mung bean bag, and HDPE plastic bead bag. As compared with the firm surface, there was a significant decrease in MVL, EPE, and MXE when subjects

Table 1. Participants' characteristics (n = 22)

Characteristics	
Age (years)	21.1 ± 1.4
BMI (kg/m^2)	20.4 ± 1.4
Gender ratio (male:female)	11:11
Dominant stance leg ratio (right:left)	3:19

Table 2. Mean (SD) sway velocity (degrees/sec) during unilateral standing on the dominant or nondominant stance leg with the eye closed or open on 4 support surfaces (firm, foam, mung bean bag, and HDPE plastic bead bag)

	Dominant stance leg		Nondominant stance leg	
	Eyes open	Eyes closed	Eyes open	Eyes closed
Firm surface	1.2 (1.1)	5.8 (3.4)	0.9 (0.9)	4.9 (2.9)
Foam surface	1.5 (1.3)	9.5 (3.9)*	1.2 (1.1)	10.1 (3.2)*
Mung bean bag	7.2 (4.1)*,#	12.0 (0.1)*	7.6 (3.8)*,#	11.7 (1.0)*
HDPE	6.7 (4.0)*,#	11.9 (0.6)*	7.8 (3.7)*,#	11.4 (1.8)*

*Significant values at $p < 0.05$ compared with the firm surface. #Significant values at $p < 0.05$ compared with the foam surface. No significant difference was found between the mung bean bag and HDPE plastic bead bag.

Table 3. Mean (SD) limit of stability parameters (center of gravity movement velocity, endpoint excursion, maximum excursion, directional control) for 8 directions of movement (F: forward; RF: right-forward; R: right; RB: right-backward; B: backward; LB: left-backward; L: Left; LF: left-forward) during standing on 4 support surfaces (firm, foam, mung bean bag, and HDPE plastic bead bag)

	F	RF	R	RB	B	LB	L	LF
Center of gravity movement velocity (MVL) (degrees/sec)								
Firm surface	5.7 (2.7)	8.2 (2.9)	7.2 (2.5)	3.9 (1.2)	2.8 (1.0)	5.5 (1.8)	6.9 (3.3)	7.3 (2.6)
Foam surface	4.7 (1.9)	6.0 (1.9)*	5.6 (2.0)	2.8 (1.0)	2.2 (0.9)	4.6 (2.3)	5.2 (2.1)	4.7 (1.7)*
Mung bean bag	4.0 (1.5)	6.7 (2.4)	5.4 (1.7)	2.6 (0.8)	2.7 (0.9)	4.8 (1.8)	4.8 (1.9)*	4.3 (1.5)*
HDPE bag	3.9 (2.1)	6.5 (2.4)	4.9 (2.1)*	2.6 (0.9)	2.7 (1.2)	4.9 (1.8)	5.3 (2.0)	4.7 (1.8)*
Endpoint excursion (EPE) (%)								
Firm surface	90.7 (7.2)	102.3 (14.5)	78.6 (9.7)	51.4 (12.4)	49.0 (10.8)	75.8 (15.3)	88.3 (9.2)	100.0 (8.7)
Foam surface	77.5 (13.5)*	94.9 (14.4)	66.4 (12.4)	46.8 (12.7)	45.5 (13.6)	63.4 (15.3)	73.5 (12.1)*	83.7 (15.3)*
Mung bean bag	52.5 (11.7)*,#	72.7 (13.3)*,#	49.1 (11.1)*,#	34.7 (10.1)*	39.2 (9.9)	53.7 (17.7)*	45.3 (12.3)*,#	57.1 (11.8)*,#
HDPE bag	53.8 (12.6)*,#	70.3 (13.5)*,#	43.8 (11.9)*,#	37.6 (9.8)*	43.4 (11.5)	59.6 (14.2)*	49.5 (13.1)*,#	59.6 (15.2)*,#
Maximum excursion (MXE) (%)								
Firm surface	102.1 (5.7)	111.1 (7.0)	90.7 (6.0)	61.2 (12.9)	58.5 (12.2)	86.9 (11.0)	96.5 (5.1)	107.5 (3.7)
Foam surface	93.9 (12.1)	104.9 (8.2)	78.8 (12.4)*	57.2 (14.5)	54.2 (15.4)	76.6 (14.5)	82.5 (9.9)*	98.4 (10.6)
Mung bean bag	63.0 (9.8)*,#	85.6 (8.8)*,#	59.6 (9.0)*,#	46.8 (11.5)*	47.8 (12.7)	64.4 (16.7)*,#	54.7 (11.5)*,#	65.9 (11.8)*,#
HDPE bag	63.7 (13.4)*,#	80.9 (11.4)*,#	51.5 (10.7)*	47.5 (11.1)*	51.7 (11.3)	71.0 (14.1)*	57.2 (12.1)*,#	68.9 (15.4)*,#
Directional control (DCL) (%)								
Firm surface	89.5 (4.7)	89.8 (3.0)	72.1 (8.6)	35.4 (16.2)	62.6 (25.4)	61.6 (17.1)	85.7 (6.1)	85.3 (4.1)
Foam surface	84.8 (4.8)	87.9 (3.9)	66.2 (9.3)	36.9 (22.1)	56.9 (24.9)	55.6 (22.8)	75.4 (8.3)	82.2 (5.9)
Mung bean bag	81.9 (7.9)	86.0 (7.0)	58.6 (15.2)	35.9 (24.0)	59.6 (24.2)	63.3 (21.3)	72.8 (12.2)	78.6 (8.3)
HDPE bag	82.3 (8.2)	84.9 (7.8)	51.2 (18.4)*	41.2 (22.6)	60.1 (29.9)	67.0 (18.0)	74.0 (10.0)	76.5 (8.4)

*Significant values at $p < 0.05$ compared with the firm surface. #Significant values at $p < 0.05$ compared with foam surface. No significant difference was found between the mung bean bag and HDPE plastic bead bag.

stood on the foam surface, mung bean bag, and HDPE plastic bead bag. However, no significant difference was found in these parameters between the foam surface, mung bean bag, and HDPE plastic bead bag. Interestingly, as compared with the foam surface, there was a significant decrease in EPE and MXE when subjects stood on the mung bean bag and HDPE plastic bead bag. No significant difference between the mung bean bag and HDPE bag was found for any direction. For DCL, there was only a significant decrease in the right direction when subjects stood on the HDPE plastic bead bag.

DISCUSSION

This study was conducted to determine the efficacy of unstable surfaces (i.e., foam pad, mung bean bag, and HDPE plastic bead bag) in causing dynamic and static postural stability disturbance. The results showed that the foam pad, mung bean bag, and HDPE plastic bead bag significantly disturbed both static and dynamic postural stability. However, their efficacies in causing postural stability disturbance were not the same. Both the mung bean bag and HDPE plastic bead bag were better than the foam pad in terms of efficacy in causing both static and dynamic postural stability disturbance. Both the mung bean bag and HDPE plastic bead bag disturbed static stability in both the eyes-open and eyes-closed conditions, whereas the foam pad did so only in the eyes-closed condition. Additionally, greater reductions in limit of stability, particularly EPE and MXE, were found for the mung bean bag and HDPE plastic bead bag as compared with the foam pad.

These results may be explained by the fact that both the mung beans and HDPE plastic beads were in nodule form. Previous studies have shown that a nodular texture could affect upright postural stability by disturbing somatosensory system functioning via cutaneous receptors[13)]. These receptors are sensitive to spatiotemporal scales of mechanical energy that discriminate acceleration, velocity, and intensity of action[14, 15)]. In addition, the nodule forms of the mung beans and HDPE plastic beads allowed them to move in a multidirectional manner when a load was applied to them. In contrast, the foam pad has a viscoelastic property that allows it to deform in proportion to the load and elastic modulus—the material's resistance to being transiently distorted when a load is applied to it[16)]. Standing on foam would produce a compressive load, which could increase its stiffness and enable participants to feel the sense of a firm surface underneath[7)]. Accordingly, participants may find it easier to stay still or move while standing on a foam surface than to stand on a surface with a nodule texture like mung beans or HDPE plastic beads.

Furthermore, postural control requires reliable information from vestibular, visual and somatosensory inputs. If one of them is disturbed, the ability to control balance will be decreased. Palm et al. demonstrated in healthy subjects that the eyes-closed condition induced a 3-fold increase in postural sway during quiet stance as compared with the eyes-open condition, and visual feedback significantly enhanced postural stability[17)]. Likewise, using electromyography recording, Braun et al. revealed that standing on unstable supporting surfaces with the eyes closed required greater lower muscle activities than standing on unstable supporting surfaces with the eyes open[18)]. These results suggested that controlling static posture while standing with the eyes closed is more challenging than standing with the eyes open. The results from this study show that the mung bean bag and HDPE plastic bead bag disturbed the static single-leg stance in both the eyes-closed and eyes-open conditions. In contrast, the foam pad disturbed the static single-leg stance only in the eyes-closed condition. It can therefore be assumed that both the mung bean bag and HDPE plastic bead bag are better than the foam pad in terms of efficacy in causing postural stability disturbance in the single-leg stance.

No significant difference in postural disturbance was found between the mung bean and HDPE plastic bead bag. This result might be due to the similarity in the nodule textures of these two materials, which might disturb postural control in the same way. Thus, both the mung bean and HDPE plastic bags could be used to disturb postural stability. The major advantages of mung beans are that they are cheap and easy available, even in the rural area. Although HDPE plastic beads are not easily available, the major advantage of HDPE plastic beads is that they have longer durability as compared with mung beans. However, both of them are heavier than the foam pad. Hence, it is not convenient for therapist to carry for testing or training.

In conclusion, this study demonstrated that dynamic and static postural stability exhibited significantly greater interference with the mung bean bag and HDPE plastic bead bag as compared with the firm surface and foam pad. No significant difference in efficacy in causing postural stability disturbance was found between the mung bean bag and HDPE plastic bead bag. These results suggested that both the mung bean bag and HDPE plastic bag could be used as a low-cost tool for balance assessment instead of using a foam pad in healthy young adults. Moreover, they are easily available, even in rural areas. A limitation of this study was that the balance abilities were assessed only in healthy young adults. Further study is needed to confirm the effect of these materials in other age groups, as well as in individuals with balance problems. In addition, the effect of balance training using the mung bean bag and HDPE plastic bead bag needs to be further investigated.

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