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ORIGINAL ARTICLE

Evaluating the Efficacy of Natural Rubber Pads for Balance Training in Community-Dwelling Older Adults: An Experimental Study

[1]Chuanpis Boonkerd, [1]Teerapat Laddawong, [1]Suteera Jaidee, [1]Thanawat Kitsuksan*

[1]Department of Physical Therapy, Faculty of Allied Health Sciences, Thammasat University, Pathum Thani, Thailand.
***. Corresponding Author: Thanawat Kitsuksan**; **E-mail:** Thanawat.k@allied.tu.ac.th

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ABSTRACT

Background. Enhancing balance function is crucial for fall prevention and maintaining quality of life among the elderly. **Objectives.** This study aimed to evaluate the effectiveness of balance training using natural rubber pads compared to Airex® foam pads and firm surfaces in healthy older adults. **Methods.** Ninety healthy older adults aged 55-65 were randomly assigned to one of three groups: training on natural rubber pads, Airex® foam pads, or firm surfaces. Participants completed a 4-week balance training program. Balance performance was assessed before and after the intervention using the Berg Balance Scale (BBS), Thai Falls Efficacy Scale-International (Thai FES-I), Timed Up and Go Test (TUGT), One-Leg Standing Test (OLST), Chair Stand Test (CST), and Tandem-Stance Test (TST). Data were analyzed using a two-way mixed-model ANOVA to evaluate differences in balance performance among the three groups. **Results.** The natural rubber pad group exhibited significant improvements in balance performance across all assessment tools (BBS, Thai FES-I, TUGT, OLST, CST, and TST) after the 4-week intervention ($p<0.05$). Notably, this group performed better in the TUGT and CST than the Airex® foam pad group ($p<0.05$). **Conclusion.** The findings suggest that natural rubber pads are an effective and cost-efficient alternative to Airex® foam pads for balance training in healthy older adults. The natural rubber pads provided an unstable yet supportive training environment, leading to significant improvements in balance performance compared to firm surfaces and offering benefits comparable to those of commercial foam pads, potentially at a lower cost.

INTRODUCTION

Maintaining postural stability is essential for preventing falls and facilitating effective movement in daily activities. Postural control is a complex process involving the management of the center of gravity (COG) within the base of support (BOS) amidst external disturbances. This process relies on two fundamental aspects: stabilization (maintaining an upright posture) and orientation (coordinating movement within the environment) (1). Balance can be categorized into static balance, which involves maintaining stability while stationary, and dynamic balance, which entails maintaining stability and coordination during movement (2). Effective balance is achieved through the integration of sensory input and motor responses. The visual system provides spatial orientation and environmental context, while the vestibular

system detects head movements and orientation relative to gravity. Proprioception offers feedback from joint and muscle receptors regarding body position and movement, and the motor system executes corrective postural adjustments based on this sensory input (3).

Age-related degeneration in the musculoskeletal and nervous systems, particularly affecting proprioception, significantly impairs postural control, increasing the risk of falls among older adults. Approximately 30% of individuals aged 65 and older experience at least one fall annually (4). These falls often lead to severe injuries, including musculoskeletal trauma, head injuries, disability, and even death (5). Balance training programs enhance postural control and stability, reduce fall risk, improve mobility, and enhance daily living activities. Such programs frequently involve exercises that require standing on various surfaces and are commonly used in physical therapy for patients with balance impairments. Previous research indicates that training on unstable surfaces, such as foam mats, is more effective in improving balance than training on stable surfaces (6, 7). This effectiveness is attributed to the increased stimulation of skin receptors in the feet and proprioceptive receptors in the muscles and joints.

Various balance training equipment, including foam pads, balance boards, and training cushions, each with distinct applications, are available. Foam pads are often preferred for elderly patients due to their smoother and more stable surface (8). However, foam pads can be costly due to their reliance on imports.

This study explores the potential of low-cost, readily available natural rubber pads as an alternative for balance training in older adults. We seek to evaluate the effectiveness of natural rubber pads compared to commercial foam pads, such as the Airex® foam pad, in improving balance. We hypothesize that balance training with natural rubber pads will yield similar balance outcomes to those observed with commercial foam pads and will be more effective than training on a stable surface.

MATERIALS AND METHODS

Participant and Procedures. The study, approved by the Thammasat University Ethical Review Board (COA No. 035/2563) and registered as a clinical trial (TCTR20201215009), aimed to evaluate the effectiveness of natural rubber pads for balance training in community-dwelling older adults. The minimum number of required participants was determined using G*Power (v.3.1.9.7). An a priori power analysis for ANOVA indicated that a sample size of 90 participants was sufficient to reliably detect an effect size (d) of 0.37 (6) with 95% power at a significance level (α) of 0.05. Therefore, ninety healthy participants aged 55 to 65 years were recruited based on criteria including independence in daily activities (Barthel ADL index score ≥12), no medical or neurological conditions affecting participation, and engagement in regular physical activity (at least 2-3 exercise sessions per week totaling ≥30 minutes per day). Exclusion criteria were visual impairments, musculoskeletal or neurological disorders affecting balance, cardiovascular or respiratory limitations, and perceptual deficits.

Participants were randomly assigned to one of three groups: a natural rubber pad group, an Airex® foam pad group, and a control group trained on a firm surface without specialized equipment, as shown in Figure 1. Randomization was achieved using a computer-generated sequence to ensure unbiased group assignment. Outcome assessors were blinded to group allocation to minimize bias throughout the assessment process. Participants were also instructed not to discuss their group assignment to avoid potential bias in their performance.

Initially, ninety healthy individuals aged 55 to 65 were recruited for the study. Of these, twenty participants withdrew—fifteen due to the COVID-19 pandemic and five for other reasons. The remaining participants had well-matched baseline characteristics across the three groups, with no statistically significant differences in age, weight, height, or Barthel ADL index, thereby supporting the validity of the subsequent comparisons regarding the balance training outcomes. Although there were slight variations in gender distribution and marital status, these are unlikely to have influenced the results significantly. The Barthel ADL index scores, close to the maximum of 20 for all groups, indicated that participants were generally independent in daily activities, reducing potential confounding factors related to functional impairments.

Training Protocol. Participants were randomly allocated to a natural rubber pad group,

an Airex® foam pad group, and a control group trained on a firm surface without specialized equipment. Each group underwent a standardized balance training program comprising 40-minute sessions conducted thrice weekly for four weeks. The training protocol, adapted from Hirase et al. (2015) (6), included exercises such as double-leg standing, one-leg standing, standing with neck hyperextension, free leg swing, heel, and toe raises, standing with neck and trunk rotation, floor touching, walking in place, sideways walking, and forward walking. The exercise intensity and progression were carefully monitored to ensure consistency across groups.

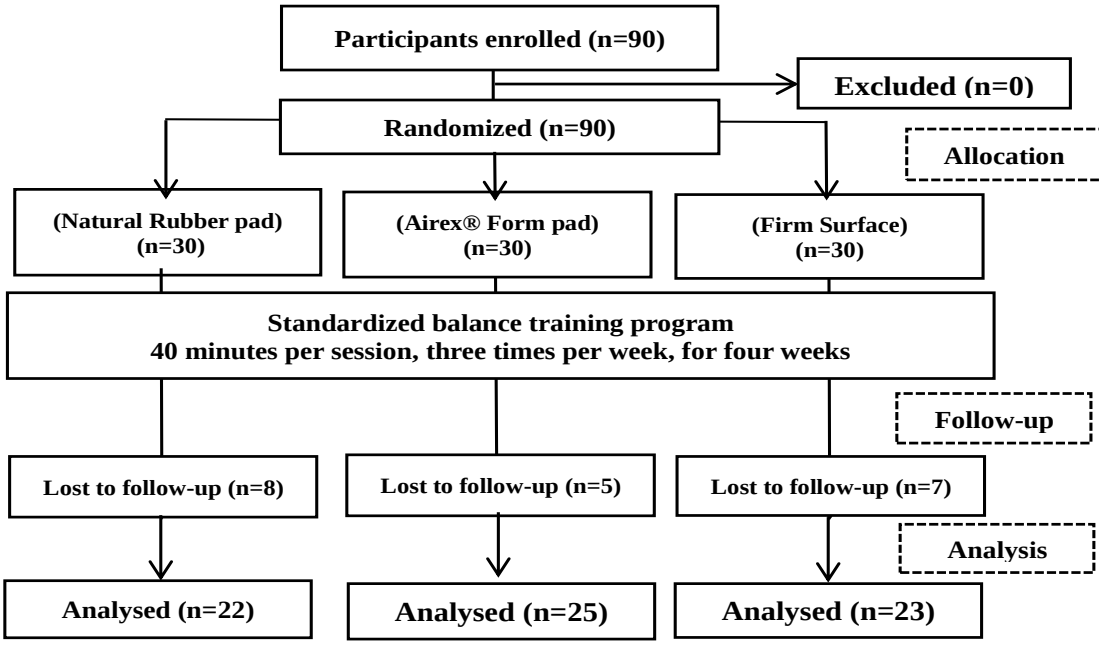

Figure 1. Consort flow diagram of enrolled participants in a randomized controlled trial.

Measures. Baseline assessments included the Berg Balance Scale (BBS). The Berg Balance Scale is a highly reliable assessment tool with strong inter-rater reliability (ICC = 0.98) and intra-rater reliability (ICC = 0.99). It exhibits high internal consistency, with Cronbach's alpha greater than 0.83 (9). The Thai FES-I (Falls Efficacy Scale-International) is a well-validated tool, showing moderate inter-rater reliability with an ICC of 0.96. It also exhibits strong internal consistency, with a Cronbach's alpha of 0.95 (10). Timed Up and Go Test (TUGT). The Timed Up and Go Test (TUGT) demonstrates excellent test-retest reliability, with an ICC of 0.97, among community-dwelling elderly individuals (11). One-Leg Standing Test (OLST) is a highly reliable assessment, with an ICC ranging from 0.84 to 0.97 and an accuracy between 0.66 and 0.99 (12). The Chair Stand Test (CST) demonstrated strong reliability, with ICC values of 0.974 (13). Lastly, the Tandem-Stance Test (TST). When used with community-dwelling individuals, the Tandem-Stance Test shows a sensitivity of 55% and a specificity of 94% (14). The TUGT assessed functional mobility and balance by measuring the time required for participants to rise from a seated position, walk 3 meters, turn, and return to sit down. Shorter completion times indicated superior mobility and balance. The OLST evaluated single-leg balance by recording the duration a participant could maintain a one-leg stance. A longer duration indicated better balance and a reduced risk of falls. The CST assessed lower body strength and endurance by counting the number of times a participant could stand up from a seated position within 30 seconds. A higher count reflected greater lower limb strength and functional capacity. The TST measured static balance by timing how long participants could maintain a tandem stance. A longer duration without losing balance indicated better static balance.

Statistical Analysis. To determine the suitability of parametric statistical methods, the normality of the data was assessed using the

Shapiro-Wilk test. A two-way repeated-measures analysis of variance (ANOVA) was then performed using IBM SPSS Statistics version 22.0 (IBM Corp., 2013). This analysis evaluated the effects of two independent variables: the type of training (natural rubber pad, Airex® foam pad, firm surface) and the time factor (pre-training, post-training) on the outcome measures. All results were reported as mean ± standard deviation (SD), and statistical significance was set at $p<0.05$. Effect sizes and 95% confidence intervals were also calculated to provide a more comprehensive understanding of the results.

RESULTS

The general characteristics of the participants at baseline are summarized in Table 1. Pre-training analyses revealed statistically significant differences between groups in the BBS, Thai FES-I, and TST measures ($p<0.05$). However, no significant differences were observed for the OLST and CST measures ($p>0.05$).

Table 1. Physical characteristics of the research participants (N=70).

Variables	Natural Rubber pad (n=22) (Mean ± SD)	Airex® Form pad (n=25) (Mean ± SD)	Firm Surface (n=23) (Mean ± SD)	*p*-value
Sex				
- **Male**	3	6	3	
- **Female**	19	19	20	
Marital status				
- **Single**	4	6	5	
- **Married**	13	11	16	
- **Divorced**	5	8	2	
Age (years)	59.40 ± 12.30	61.26 ± 3.09	61.12 ± 4.15	0.66
Weight (kg)	57.79 ± 7.84	67.39 ± 25.02	62.90 ± 9.73	0.60
Height (m)	1.57 ± 6.21	1.58 ± 7.56	1.56 ± 12.18	0.29
Barthel ADL Index	19.81 ± 0.50	19.64 ± 0.91	19.82 ± 0.67	0.56

Values are presented as mean and standard deviation.

The balance and functional measurement outcomes of three different balance training interventions following four weeks of training are presented in Table 2. The natural rubber pad group exhibited significant improvements across several measures. Specifically, BBS scores increased from 51.09 ± 5.07 to 51.81 ± 4.01, OLST scores improved from 38.27 ± 21.02 to 88.06 ± 104.21, and TST scores rose from 85.04 ± 50.00 to 162.45 ± 93.31. Additionally, this group demonstrated a reduction in fear of falling, as evidenced by a decrease in Thai FES-I scores from 21.90 ± 3.92 to 20.36 ± 2.59, and faster completion times in the Timed Up and Go Test (TUGT), which improved from 9.24 ± 1.42 to 7.28 ± 0.83.

The Airex® foam pad group also showed notable improvements. BBS scores increased from 52.78 ± 1.31 to 54.78 ± 1.47, Thai FES-I scores decreased from 18.69 ± 1.42 to 17.21 ± 1.75, and TUGT completion times improved from 11.98 ± 2.09 to 10.63 ± 2.00. Additionally, OLST scores rose from 41.60 ± 29.78 to 82.91 ± 62.10, and TST scores increased from 173.56 ± 77.73 to 249.21 ± 123.93.

The control group exhibited some improvements in balance after four weeks, with BBS scores increasing from 54.52 ± 2.02 to 55.16 ± 1.34 and Thai FES-I scores decreasing from 22.12 ± 3.97 to 19.48 ± 3.19 ($p<0.05$). However, no significant improvements were observed in TUGT, OLST, or CST measures ($p>0.05$). Notably, the TST score in the control group showed a significant decrease, from 196.87 ± 149.08 to 123.90 ± 102.45 ($p<0.05$).

DISCUSSION

While statistically significant differences in baseline scores were observed between groups for BBS, Thai FES-I, and TST assessments, the natural rubber pad group exhibited lower baseline scores across several measures, including BBS, Thai FES-I, TUGT, and TST. At first glance, this might suggest a disadvantage, and it underscores the potential effectiveness of the natural rubber pad as a balance training tool. The lower initial scores indicate that the natural rubber pad group participants started with a lower balance capacity and higher fear of falling than the other groups.

This starting point provided a unique opportunity to assess the efficacy of the natural rubber pad in improving balance from a lower baseline.

Table 2. Balance and functional measures of three different balance training interventions.

Variables	Natural Rubber pad (n=22) (Mean ± SD)		Airex® Form pad (n=25) (Mean ± SD)		Firm surface (n=23) (Mean ± SD)		Time	Group	Time x Group
	Pre-test	Post-test	Pre-test	Pre-test	Pre-test	Pre-test	*p*-value	*p*-value	*p*-value
BBS	51.09 ± 5.07†	51.81 ± 4.01*,†,‡	52.78 ± 1.31	54.78 ± 1.47*	54.52 ± 2.02	55.16 ± 1.34*	0.000	0.000	0.001
Thai FES-I	21.90 ± 3.92†	20.36 ± 2.59*	18.69 ± 1.42	17.21 ± 1.75*,†,§	19.48 ± 3.19	22.12 ± 3.97*	0.000	0.000	0.000
TUGT	9.24 ± 1.42	7.28 ± 0.83*,†,‡	11.98 ± 2.09†,§	10.63 ± 2.00*	9.63 ± 1.92	9.52 ± 2.11	0.000	0.000	0.000
OLST	38.27 ± 21.02	88.06 ± 104.21*	41.60 ± 29.78	82.91 ± 62.10*	33.97 ± 46.48	48.42 ± 47.11	0.000	0.000	0.151
CST	13.00 ± 2.82	16.90 ± 5.61*,†,‡	12.13 ± 1.63	13.82 ± 2.77*	11.94 ± 2.85	13.00 ± 2.37	0.000	0.000	0.000
TST	85.04 ± 50.00†,‡	162.45 ± 93.31*,†	173.56 ± 77.73	249.21 ± 123.93*,§	196.87 ± 149.08	123.90 ± 102.45*	0.026	0.000	0.000

Values are presented as mean and standard deviation; BBS: Berg Balance Scale; Thai FES-I: Thai Falls Efficacy Scale-International; TUGT: Timed Up and Go Test; OLST: One-Leg Standing Test; CST: Chair Stand Test; TST: Tandem-Stance Test.
* Significant difference from Pre-test ($p<0.050$)
† Significant difference from firm surface ($p<0.050$)
‡ Significant difference from Airex® Form pad ($p<0.050$)
§ Significant difference from Natural Rubber pad ($p<0.050$)

This study investigated the effects of balance training using a natural rubber pad over 4 weeks, evaluating outcomes with BBS, Thai FES-I, TUGT, OLST, CST, and TST. The study's results are consistent with prior research suggesting that balance training on unstable surfaces, such as foam or natural rubber pads, effectively improves balance and reduces fall risk in older adults (6, 7). Proprioception is essential for joint awareness, particularly during dynamic activities, and it plays a significant role in joint kinesthesia, position sense, and muscle reaction time. Proprioceptive feedback is crucial for maintaining balance and postural control, which is especially important in older adults, as age-related decline in the proprioceptive system increases the risk of falls (15, 16). Our findings highlight that natural rubber and Airex® foam pads can significantly enhance balance, as evidenced by improvements in BBS, Thai FES-I, OLST, and TUGT measures. The natural rubber pad group demonstrated comparable improvements to the Airex® foam pad group, suggesting that natural rubber pads can serve as a cost-effective alternative for balance training.

The material properties of the natural rubber pad and Airex® foam pad are critical in understanding their effectiveness in balance training. Both materials withstand similar pressure levels and provide a soft, flexible surface that promotes proprioception and challenges balance. To ensure the natural rubber pad's suitability as a balance training tool, its material properties were carefully calibrated to match those of the Airex® foam pad. The pressure resistance of the standard Airex® foam pad and the prototype natural rubber pad was tested using a Universal Testing Machine (INSTRON 5566), indicating that both materials exhibit similar mechanical properties under compression. The ability of the natural rubber pad to provide similar proprioceptive stimulation to the Airex® foam pad suggests that it can be equally effective in improving balance (17). This is particularly important given the cost-effectiveness of natural rubber, making it a viable option for widespread use in community settings and resource-limited environments. Furthermore, the enhanced proprioceptive feedback provided by these materials can improve sensory integration, which is crucial for effective balance control (3, 18).

In addition to the materials used, the exercise regimen is crucial in improving balance. The exercises in this study focused on lower limb movements performed on both the natural rubber pad and Airex® foam pad. These exercises were

designed to challenge the participants' balance by introducing controlled instability, stimulating proprioceptive mechanisms, and requiring greater muscle activation (19, 20). The combination of an unstable surface and targeted lower limb exercises likely contributed to the significant improvements observed in the BBS, Thai FES-I, TUGT, OLST, CST, and TST scores. This finding aligns with previous studies emphasizing incorporating dynamic, proprioceptive-enriching activities into balance training programs for older adults (21, 22). The improvements observed in the natural rubber pad and Airex® foam pad groups are consistent with the findings of Hirase et al. (2015) (6), who studied the effects of balance training on older adults using foam pads and firm surfaces. Their study noted significant improvements in the TUGT, OLST, and TST scores after one month of training on foam pads, with CST improvements occurring after two months.

In contrast, participants who trained on firm surfaces required 3-4 months to improve significantly. In the 30-second CST, a change of at least two repetitions was shown to be a minimally clinically significant difference, according to previous research by Wright et al. (2011) (23). After undergoing balance training, the group using natural rubber pads performed better in the CST by 4 repetitions. In TUGT, the natural rubber pad groups also performed better than the Airex® foam pad group, which improved the CST by fewer than two repetitions. This could be explained by a higher repetition indicating stronger lower limb strength and functional capacity in the natural rubber pad groups following balance training. Balance training on unstable surfaces, such as natural rubber or Airex® foam pads, can enhance proprioceptive feedback and balance control more effectively and in a shorter period than training on firm surfaces (24). This study's findings reinforce the idea that incorporating unstable surfaces into balance training programs can accelerate balance and postural control improvements. Moreover, natural rubber pads, which are more accessible and cost-effective than Airex® foam pads, could make these benefits more widely available, particularly in under-resourced areas.

Despite the study's strengths, including a randomized controlled design and comprehensive outcome measures, some limitations exist. The narrow age range of participants (55-65 years) may limit the generalizability of the findings to older populations. Additionally, the short duration of the intervention (four weeks) may only fully capture the short-term effects of balance training. Future studies should consider including a more diverse age range and the retention effect of balance training during a short period to assess long-term outcomes. Further research could also explore the underlying mechanisms by which natural rubber pads influence balance, such as the role of sensory feedback and proprioceptive stimulation.

CONCLUSION

This study demonstrates that balance training with natural rubber pads is as effective as training with commercial Airex® foam pads in improving balance among community-dwelling older adults. The natural rubber pads offer a cost-effective alternative that could enhance accessibility to balance training programs. Further research is warranted to explore the long-term effects of such training and to investigate the underlying mechanisms contributing to improved balance outcomes.

APPLICABLE REMARKS

- The natural rubber pads are an effective and cost-efficient alternative to Airex® foam pads for balance training in healthy older adults.
- The natural rubber pads provided an unstable yet supportive training environment, significantly improving balance performance compared to firm surfaces.

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AUTHORS' CONTRIBUTIONS

Study concept and design: Chunapis Boonkerd, Thanawat Kitsuksan. Acquisition of data: Chunapis Boonkerd, Suteera Jaidee, Teerapat Laddawong, Thanawat Kitsuksan. Analysis and interpretation of data: Chunapis Boonkerd, Teerapat Laddawong, Thanawat Kitsuksan.

Drafting the manuscript: Chunapis Boonkerd, Thanawat Kitsuksan. Critical revision of the manuscript for important intellectual content: Chunapis Boonkerd, Teerapat Laddawong, Thanawat Kitsuksan. Statistical analysis: Chunapis Boonkerd, Teerapat Laddawong, Thanawat Kitsuksan. Administrative, technical, and material support: Chunapis Boonkerd, Suteera Jaidee, Teerapat Laddawong, Thanawat Kitsuksan. Study supervision: Chunapis Boonkerd, Teerapat Laddawong, Thanawat Kitsuksan.

CONFLICT OF INTEREST

The researchers claim no conflicts of interest.

FINANCIAL DISCLOSURE

No author has any financial interest or received any financial benefit from this research.

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ETHICAL CONSIDERATION

This study was approved by the Thammasat University Ethical Review Board (COA No. 035/2563) and registered as a clinical trial (TCTR20201215009). The present study involved human participants in experimental research. The authors obtained informed consent from all the participants before participating in this study.

ROLE OF THE SPONSOR

The sponsor had no role in the study design, data collection, data analysis, interpretation of results, manuscript preparation, or decision to submit the article for publication.

ARTIFICIAL INTELLIGENCE (AI) USE

The present study's authors did not use any artificial intelligence-based software for the paper's conceptualization, data analysis, or writing, except for general-purpose language models used for proofreading or editing assistance, where applicable.

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