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A Comparison Between Square-Stepping Exercise Program Versus Both Sides Up Ball Exercise Program For Balance Improvement In Older Adults With Balance Impairment: A Pilot Study

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ABSTRACT
Background*: Balance depends on biomechanics, sensory input, and surface conditions but declines with age, especially after 60, raising fall risks. Falls can cause serious health issues and loss of independence. Square stepping exercises (SSE) on grid mats boosts coordination, while Both Sides Up (BOSU) ball training enhances agility and stability, highlighting physiotherapy's vital role in fall prevention and balance improvement.*
Aim: *To evaluate and compare the effectiveness of SSE and BOSU ball exercises in enhancing older adults' balance.*
Method: *A pilot study involving 20 older adults (aged 60-70) assessed balance improvements. Participants met inclusion criteria (independent ambulation, mini–mental state examination (MMSE) >24, recent fall history) and exclusion criteria (severe musculoskeletal, cardiopulmonary, or neurological conditions; recent fractures; sensory or psychiatric impairments). Participants were randomly assigned to SSE (Group A) or BOSU Ball (Group B) exercises, training 45 minutes daily, five times a week, for four weeks. The Berg Balance Scale (BBS), Timed Up and Go (TUG) Test, and Modified Clinical Test of Sensory Interaction on Balance (M-CTSIB) evaluated balance before and after the intervention. Data analysis was performed using a paired t-test.*
Result: *The study found significant balance improvements in both groups ($p < 0.05$). However, the SSE group exhibited more substantial balance enhancements compared to the BOSU ball exercises group.*
Conclusion: *In conclusion, both SSE and BOSU ball exercises improved balance in older adults, with SSE proving more effective in enhancing balance among the elderly.*
Key Words: *Balance impairment, Balance improvement, Both sides up ball exercise, Square-stepping exercise, Older adults*

INTRODUCTION

A body is upright when its center of gravity stays within its base of support. Balance is either dynamic or static: dynamic balance is essential for movements like walking or reaching, while static balance helps maintain stability during stillness, such as sitting or standing. To stay balanced, the body integrates input from the vestibular system, vision, and somatosensory feedback to assess its spatial orientation and ensure equilibrium [1]. Carr and Shepherd (1998) highlight that balance and movement depend on environmental context, while Woollacott and Shumway-Cook (1996) consider balance essential for voluntary actions. Adapting to shifts in center of gravity requires understanding individuals' base of support [2].

Falls are a major issue in older adults, considered a key geriatric syndrome along with confusion, incontinence, imbalance, and iatrogenic issues—collectively contributing significantly to elderly morbidity [3]. Falls cause 30–50% of accidents, with 5–6% resulting in serious injuries and 5% in fractures. They lead to 60% of brain injuries and 90% of femur and wrist fractures. In the elderly, falls are a leading cause of injury-related deaths. Risk factors are either intrinsic—like muscle weakness, balance issues, or cognitive decline—or extrinsic, such as uneven surfaces. Recognizing these factors is crucial for fall prevention and safety [4].

Balance training boosts confidence in maintaining stability, reducing fall-related fear, encouraging faster walking, and enhancing overall physical performance, functionality, and self-efficacy in individuals [5].

Effective balance is key to postural stability and fall prevention. While traditional balance training emphasizes standing exercises to control the center of mass, it may not fully prepare individuals for real-life challenges. Real-world scenarios require quick reactions, accurate foot placement, and adaptive stepping. Square stepping exercise (SSE) mats, typically made of non-slip rubber and arranged in a 3x3 grid, are often used to improve these skills. Participants follow increasingly complex step patterns to boost coordination and agility in dynamic settings [6].
The Both Sides Up (BOSU) ball features a rubber dome atop a flat plastic base, resembling half a Swiss ball. It can be used on either side. Popular among athletes and professionals, research shows its unstable surface aids proprioceptive training, enhancing coordination, agility, and lower-limb strength [7].

METHODS

This pilot study took place at the physiotherapy department of Sharda Hospital in Greater Noida, Uttar Pradesh, with a sample of 20 older adults aged 60 to 70 years, including both males and females. Inclusion criteria included: (1) ability to walk 10 meters independently; (2) a Mini Mental State Examination score above 24; (3) a history of at least one recent fall, assessed via the Morse Fall Scale. Exclusion criteria included: (1) severe musculoskeletal, cardiopulmonary, or neurological conditions; (2) recent fractures or injuries; (3) psychiatric, visual, vestibular, sensory, or hearing disorders.
One of two intervention groups, each with ten participants, was randomly assigned to the participants: SSE was employed to train Group A, while BOSU ball exercises were employed to train Group B.
Intervention: Two experimental groups engaged in a structured 4-week exercise intervention, comprising 45-minute training sessions conducted five times per week.
Group A: SSE Training
Each SSE session started with a 10-minute warm-up where participants walked freely at their own pace, performing joint-mobility exercises. In the main activity, they stood behind a mat and followed instructor-demonstrated stepping patterns. Initially, they practiced the patterns individually until they were memorized, with instructors offering support when needed. Once confident, participants performed the steps to a metronome-set tempo. The patterns included unilateral movements, where one leg stayed in place while the other stepped on designated squares, alternating legs. Additional exercises included bilateral movements, requiring alternating steps with both legs (Figure 1).

Figure 1: An individual performing a SSE
Group B: BOSU-Ball Exercise Training
The BOSU-ball sessions also began with a 10-minute warm-up. Exercises were initially performed with assistance and gradually transitioned to unassisted execution. The exercises included:

1. Unilateral Heel Raise: One foot on the ball, raising and lowering the heel of the opposite foot (5–8 repetitions).
2. Marching: Marching on the ball for 20 counts, repeated 5–8 times.
3. Knee Bends: Bending both knees while standing on the ball, maintaining the position for 10 counts (5–8 repetitions).
4. Split Stance with Torso Rotation: One foot on the ball, rotating the torso with raised arms (5–8 repetitions).
5. Single-Leg Stands: Standing on one leg on the ball, holding for 10 counts (5–8 repetitions) (Figure 2).

Figure 2: An individual performing a BOSU ball exercise.

Outcome Measures: The Berg Balance Scale (BBS), the Timed Up and Go (TUG) test, and the Modified Clinical Test for Sensory Interaction on Balance (CTSIB-M) were among the outcome measures that were evaluated before and after the four-week intervention.

Data Analysis

Statistical analysis was conducted using SPSS software, employing a paired t-test to evaluate the data. Statistical test used for normality of distribution was Shapiro-Wilk Test

Hypothesis

- There will be significant effect of SSE program over BOSU ball exercise program among elderly people who have balance issues.
- There will be significant effect of BOSU ball exercise program over SSE program among elderly people who have balance issues.

RESULTS

Table 1: Demonstrating the statistical contrasts among the SSE (Group A) and BOSU ball exercise (Group B) (BBS).

Time of the assessment	Groups					
	Group A			Group B		
	Mean	SD	p-value	Mean	SD	p-value
Pre	31.50	6.62	0.0001	31.50	7.29	0.0001
Post	38.70	6.80		36.40	8.28	

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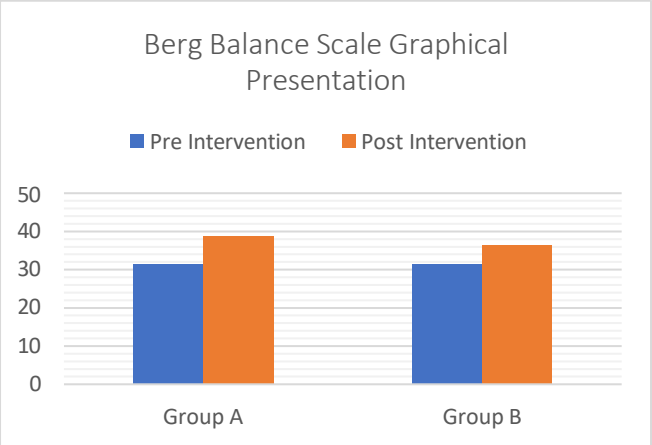
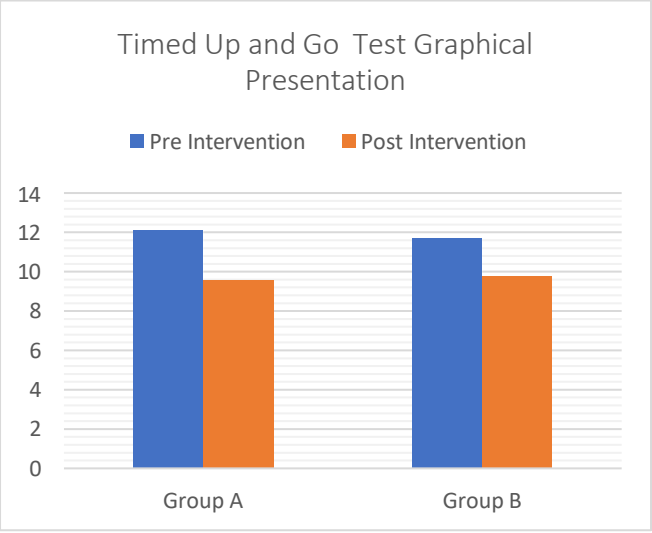


The pre-training mean BBS score in Group A was 31.50 ± 6.62, which significantly improved to a post-training mean of 38.70 ± 6.80, as shown in Table 1. This indicates a notable increase in BBS scores following SSE training (p-value = 0.001), highlighting its effectiveness in enhancing balance in the elderly population. Similarly, Group B demonstrated a pre-training mean BBS score of 31.50 ± 7.29, which significantly increased to 36.40 ± 8.28 after BOSU ball training exercises. This improvement (p-value = 0.001) confirms the effectiveness of BOSU ball training exercises in improving older people's balance.

Table 2: Demonstrating the statistical contrasts among the SSE (Group A) and BOSU ball training (Group B) exercises (TUG score).

Time of the assessment	Groups					
	Group A			Group B		
	Mean	SD	p-value	Mean	SD	p-value
Pre	12.10	1.52	0.0001	11.70	1.33	0.0001
Post	09.60	0.84		09.80	0.78	

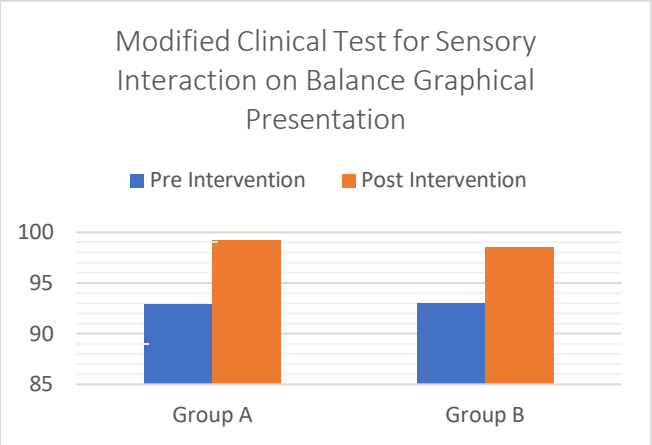


Before training, Group A's mean TUG test score was 12.10 ± 1.52, but after 4 weeks, it considerably improved to 9.60 ± 0.84, as shown in Table 2. The SSE training group showed a significant decrease in TUG scores (p-value = 0.0001), implying that SSE improve older individuals' balance. According to Table 2, Group B's pre-training mean TUG score was 11.70 ± 1.33, however after 4 weeks; it significantly

improved to 9.80 ± 0.78. The effectiveness of BOSU ball exercises in improving balance in older adults was confirmed by a substantial decline in TUG scores in the BOSU ball training group (p-value = 0.0001).

Table 3: Demonstrating the statistical contrasts among the SSE (Group A) and BOSU ball training (Group B) exercises (M -CTSIB).

Time of the assessment	Groups					
	Group A			Group B		
	Mean	SD	p-value	Mean	SD	p-value
Pre	92.90	9.29	0.015	93.00	7.67	0.006
Post	99.20	5.88		98.50	8.92	



The pre-training mean M-CTSIB score for Group A was 92.90±9.29, which showed a significant improvement to 99.20±5.88 after training, as detailed in Table 3. This demonstrates a notable enhancement in balance following SSE (p = 0.015) among the elderly. Similarly, Group B exhibited a pre-training mean M-CTSIB score of 93.00±7.67, which significantly increased to 98.50±8.92 after undergoing BOSU ball training exercises. This improvement (p = 0.006) further confirms the effectiveness of BOSU ball exercises in enhancing balance in the elderly individuals.

Table 4: Representing the groups' contrasts between the changes of BBS Score.

	Mean	SD
Group A	-7.20	2.89
Group B	-4.90	2.28

Table 4 shows mean change in balance scores for Group A was 7.20 ± 2.89, while that for Group B was 4.90 ± 2.28, as detailed in Table 4. A significant improvement in BBBS scores was observed post-training, with a p-value of 0.0001. These findings imply a statistically significant enhancement in balance among the elderly population across both groups, with the Group A demonstrating a greater increase in BBS scores compared to Group B.

Table 5: Representing the groups' contrasts between the changes of TUG Score.

	Mean	SD
Group A	2.50	0.972
Group B	1.90	0.994

Table 5 shows Group A showed a mean difference of 2.50 ± 0.972, while the Group B demonstrated a mean difference of 1.90 ± 0.994, as presented in Table 5. A significant enhancement in the TUG test was

observed post-training, with a p-value of 0.0001. This suggests a notable improvement in balance performance in the elderly cohort when comparing the two groups, with Group A demonstrating a more pronounced reduction in TUG scores.

Table 6: Representing the groups' contrasts between the changes of M-CTSIB Score.

	Mean	SD
Group A	-6.30	5.638
Group B	-5.50	5.836

Table 6 shows Group A showed a mean change of 6.30 ± 5.638, while Group B showed a mean change of 5.50 ± 5.836. Post-training, the M-CTSIB scores improved significantly, with a p-value < 0.01. This finding highlights a notable enhancement in balance among the elderly participants, within Group A demonstrating a greater reduction in M-CTSIB scores compared to Group B.

DISCUSSION

This study compared the effectiveness of the SSE and the BOSU ball exercise in improving balance among older adults with balance impairments. Both interventions demonstrated benefits, with unique advantages linked to their design. Results show that both exercises improve balance by enhancing postural control, stability, and coordination. The SSE program, emphasizing stepping patterns and cognitive engagement, is particularly effective for dynamic balance and fall prevention by boosting proprioception and multisensory integration. In contrast, the BOSU ball exercise provides a dynamic workout, strengthening core muscles and improving overall mobility while offering an interactive and enjoyable experience.

Exercise enhances balance in older adults, with Paterson et al. emphasizing improved joint flexibility despite aging-related limitations in daily activities [8]. Balance includes dynamic and static control, influenced by sensory inputs. BOSU ball exercises improve posture; reduce fall fear [7]. Developing exercise programs based on current research, focusing on movement speed, range, complexity, and cognitive demands, prevents falls [9]. Mantana V et al. found a strong link between fear of falling, balance impairment, muscle weakness, and delayed TUG performance [10].

Bhanusali et al. propose that SSE can effectively aid rehabilitation and public health, highlighting its benefits, including faster reaction time that boosts information processing and psychomotor skills [11]. BOSU ball exercises improve balance in older adults, with participants finding them enjoyable, valuable, and motivating. These exercises offer a safer, more effective and engaging method for balance training programs [12].

Jianhua Cui et al. discovered that long-term Tai Chi practice enhances proprioception, reducing vestibular reliance and improving balance complexity [13]. Yazmín et al. emphasize that older adults' neuromotor systems exhibit lasting plasticity with repeated perturbations, highlighting the effectiveness of perturbation exercises in reducing fall risk [14].

N.P. Bestari et al. discovered that SSE enhances dynamic balance, lowering fall risk in the elderly, and is a key intervention for fall prevention [15]. Berihu Fisseha et al. emphasized that SSE improve balance, reduce fall injuries, alleviate fear, and enhance health perceptions [16]. Masato Kawabata et al. demonstrated that hybrid SSE boosts cognitive, physical, psychological, and group functions, enhancing seniors' health [17].

Arun Thachil et al. found SSE improves lower extremity strength and confidence, reducing fall risk in young-old females [18]. Yin-Hsiang Wang BS et al. discovered that older adults participating in structured SSE showed improvements in motor function, including balance, fall risk, and agility, enhancing overall physical performance and mobility [19]. Munseef Sadaqa et al. show that physical exercise enhances balance, lower limb strength, and mobility, while reducing fall incidence and injuries. They call for more research on fall prevention, especially in vulnerable populations [20].

N. Eckardt et al. found that all treatment groups showed equal improvements in lower-extremity power, endurance, and balance. Free-weight unstable surfaces were equally effective as machines, using lower loads and reducing fall risks [21]. L.K. Allison et al. showed that a balance exercise program enhancing multisensory integration improved balance, multisensory reweighting, and lower limb strength, supporting the use of sensory-challenging exercises to reduce fall risks [22]. Mantana V et al. found a strong link between fear of falling and balance, with poor balance worsening it, impairing muscle strength, and slowing TUG performance, highlighting the need for consistent monitoring and intervention [10]. Ranchana Nokham et al. found that SSE effectively enhanced short-term balance in older adults, potentially lowering their fall risk [23]. E. Thomas et al. state that balance is a complex ability that improves through various exercise methods. Encouraging physical activity in older adults is crucial, as inactivity negatively impacts balance performance [24]. S. S. Darijani et al. suggest that older adults with balance issues benefit from neurofeedback therapy, sensorimotor exercises, and their combination, improving balance, endurance, and fall prevention, though further research is needed [25].
The study indicates that SSE is more effective than BOSU ball exercises for enhancing balance and lowering the risk of falls among senior citizens. Its diverse stride patterns and enhanced coordination make it a superior preventative strategy, engaging multiple muscle groups and improving neuromuscular coordination, thus boosting stability and posture control.

CONCLUSION

The study suggests that both SSE and BOSU ball exercises improved balance in older adults. The SSE was safe, effective, practical, and feasible. BOSU ball exercises were engaging and enjoyable, but the SSE proved more successful in improving older people's balance

ETHICAL CLEARANCE

Taken from institutional ethical committee Ref. No. SU/SMS&R/76-A/2024/280

AKNOWLEDMENT

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CONFLICT OF INTERESTS

Regarding the publishing of this work, the authors state they don't have no conflicts of interest.

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CONSENT FORM

• TITLE OF THE STUDY "A Comparison Between Square-Stepping Exercise Program versus Both Sides Up Ball Exercise Program for Balance Improvement in Older Adults with Balance Impairment: A Pilot Study"

• SUBJECT'S NAME---------- ID NO.---------- AGE ---------- SEX ------

• PLEASE TICK IF YOU AGREE

1. I confirm that I have read and understood the information on sheet for the above study dated _____ and have had the opportunity to ask questions. ☐

2. I understand that my participation in the study is voluntary and that I am free to withdraw at any time, without having to give a reason, and without my rights and privileges being affected. ☐

3. I understand that my data would be kept confidential al but individuals authorized by the Principal Investigator, the ethics committee of the institute where the study will be conducted and government regulatory authority will have access to my records both in respect of the current study and further research that may be conducted in relation to it. Even if I withdraw, I agree to this access. However, I understand that my identity will not be revealed and confidentiality of information will be maintained. ☐

4. I agree not to restrict the use of any data or results that arise from this study for academic purpose. ☐

5. I agree to voluntarily take part in the above study. ☐

• Signature / Thumb impression of the subject or a legally acceptable representative (LAR): _____ Date: _____

• Signatory's name: _____

• Study investigator's signature: _____ Date: _____

• Study investigator's name: _____

• Mandatory where subject or LAR has provided thumb impression:

• Signature of the witness: _____ Date: _____

• Name & Address of the witness: _____

• Relation to the subject, if any: _____

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SCHOOL OF MEDICAL SCIENCES AND RESEARCH & SHARDA HOSPITAL

SHARDA UNIVERSITY
Beyond Boundaries

Institutional Ethics Committee

Ref. No. SU/SMS&R/76-A/2024/280 **Date: 06/12/2024**

Akanksha Dhaundiyal
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Akanksha Dhaundiyal,

Please refer to the minutes of meeting of the Institutional Ethics Committee meeting held on the 20th November, 2024 at 11.00 AM onwards.
The proposed project titled **"A Comparison between Square Stepping Exercise Program versus Both Sides Up Ball Exercise Program for Balance Improvement in Older Adults with Balance Impairment."** **Principal Investigator Akanksha Dhaundiyal**, MPT, Neurology Student, Department of Physiotherapy, SSAHS, under the supervision of Dr. Meenakshi Verma, Assistant Professor, Department of Physiotherapy, has been approved by the Institutional Ethics Committee, SMS&R and Sharda Hospital, Sharda University, as for the human ethics issues, are concerned, in the meeting held on the 20th November, 2024 at 11.00 AM onwards, under the Chairmanship of Professor Chakra Dhar Tripathi.

Moumita Bala
06/12/24

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