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RESEARCH ARTICLE

Comparison of vestibular and somatosensory disturbances in community-dwelling older adults with balance disorder

Alieza Khalid[1], Ameera Ammar[1], Anoosha Saqib[1], Wafa Ahmed[1], Nadia Azhar[1]

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ABSTRACT

Background: Aging is natural process which is sometimes characterized by physical impairment and functional disability, leading to dependence. This study compares the effects of vestibular and somatosensory disturbances on balance performance and fall risk in older adults.

Objective: The study aims to determine and compare the effects of vestibular and somatosensory disturbances on balance performance and fall risk in older adults.

Methods: A cross-sectional study involving 402 older adults was conducted over a 12-month period. The ethical approval obtained had reference number Riphah/RCRS/REC/01427. The Berg Balance Scale BBS was employed as a standardized tool to assess balance, the modified clinical test of sensory interaction in balance (m-CTSIB) was used to evaluate individuals' reliance on sensory systems, and the Modified Dix-Hallpike maneuver was applied to detect vestibular dysfunction.

Results: The study included 52.6% females and 47.1% males, with an average age of 60.28±9.37 years. On the Berg Balance Scale, only 5% of participants were classified as high risk for falls, while 45.4% and 49.4% were in the moderate and low-risk categories, respectively. Results from the Modified Dix-Hallpike maneuver indicated 73.4% positive outcomes and 26.3% negative outcomes for vestibular dysfunction. Balance performance showed a mild positive significant correlation ($P < 0.05$). The multiple regression analysis, using the formula: Fall Risk=$\beta 0+\beta 1$ (BBS)+$\beta 2$ (m-CTSIB) demonstrated a mild to moderate negative correlation between m-CTSIB scores and fall risk.

Conclusion: The study highlights the prevalence of vestibular dysfunction in older adults and the critical role of sensory systems in balance, emphasizing the need for targeted rehabilitation to improve health outcomes and quality of life.

Keywords: Aging, Berg Balance Scale, Modified Clinical Test of Sensory Interaction in Balance, Somatosensory, Vestibular.

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Introduction:

Aging is a natural process associated with increased susceptibility to disease and death in older adults.(1) As individuals age, they often encounter physical impairment and functional disability, leading to heightened dependence.(2) "Frail, Aged" refers to those aged 65 or older experiencing chronic illness or disability for over a year. The World Health Organization (WHO) defines the elderly population as those aged 60 or older, growing at a rate of 2.4%, surpassing the general population growth rate of 1.7%. In Pakistan, the population above 65 is 12.13 million. (3) Physiological changes with aging have longitudinal effects, causing a decline in physical function that may result in difficulties in performing activities of daily living (ADLs), increased hospitalization, extended stays, and a shortened lifespan. Termed frailty, this state negatively impacts physical, mental, and social well-being, contributing to a poor quality of life (QOL). Reports indicate that 10% of adults aged 75 and above become dependent each year due to challenges in daily activities.(4)

The aging process significantly affects balance maintenance, leading to a gradual deterioration and an increased risk of falls and injuries. Achieving balance involves coordinating sensory-motor control systems,

Affiliations: [1]Riphah International University, Islamabad, Pakistan.
Correspondence: Nadia Azhar
Email: nadia.azhar@riphah.edu.pk
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including proprioception, vision, and the vestibular system. The input percentages of somatosensory, vestibular, and visual systems in balance vary (Somatosensory: 30-50%, Vestibular: 10-30%, Visual: 10-30%).(5) Balance is crucial for quiet stance, anticipatory postural responses, and compensatory postural reactions, involving the maintenance of the body's center of mass over its support base. Disruption occurs when the center of mass misaligns with the base of support. Older individuals commonly experience balance issues, with research indicating that 20% to 33% of adults aged 65 and above face balance problems, making it a prevalent concern for physicians.(6)

The control of balance relies on the vestibular system, which includes the peripheral vestibular system (sensory organs and nerves in the inner ear) and the central vestibular system (neural pathways and brain structures). Housed within the temporal bone, the vestibular system comprises three semicircular canals and two otolith organs, providing continuous updates to the brain about head movement, translation, and gravity's position. This information facilitates the vestibular-ocular reflex for gaze stability and the vestibulospinal reflex for postural stability.(7)

Classic symptoms of vestibular dysfunction include vertigo, dizziness, and imbalance, driven by abnormalities in gaze and postural stability. A Swedish survey found a 50% increase in dizziness prevalence among adults over 85. Vestibular dysfunction may lead to falls, causing severe injuries, limited mobility, and contributing to fatalities in older adults.(8)

The somatosensory system, comprising peripheral and central components, is crucial for maintaining balance control. It utilizes proprioceptive and cutaneous stimuli to convey information about the body's position and movement. Proprioception considered the sixth sense, is vital for effective interaction with the environment and fundamental to overall body function. (9)

The age-related loss of proprioception is pivotal to various geriatric disorders, particularly falls. With age, there is a shift in reliance on sensory stimuli for movement in older adults, leading to a decline in sensorimotor control of balance. Consequently, the likelihood of falls increases among older adults, correlating with higher morbidity and mortality rates and a decrease in overall functional ability.(10)

In our community, at least 19.3% of older adults report a history of falls, especially among those with co-morbidities like stroke, vision impairments, incorrect footwear, arthritis, and fractures. The National Injury Survey in Pakistan recorded an annual incidence rate of 8.85 per thousand for fall injuries. (11) Certain medications directly increase the risk of falls, contributing to 80% of hospital admissions in this age group, with 30% to 50% resulting in minor injuries and 10% in major injuries. Approximately 20% of falls in the elderly lead to serious injuries such as fractures or head injuries. Studies indicate that individuals with balance disorders score significantly lower on both ADL and IADL assessments compared to those without balance disorders. A 2022 study in the Journal of Vestibular Research revealed that older adults with severe balance impairment face greater limitations in ADLs, including walking, dressing, and showering.(12)

Physical therapy for older adults typically involves exercises targeting flexibility, endurance, strength, and balance control to enhance proprioception. A progressive increase in physical activity over time, including muscle strengthening and weight-bearing activities, is essential to prevent age-related reductions in musculature, bone density, and functional ability. Prevention strategies, such as home-based exercises like Single-leg stance, Tai chi, Heel-to-toe walk, Standing hip abduction, and yoga, can significantly reduce the risk of falls. Regular strength and balance training, as supported by a comprehensive review and meta-analysis, has shown a 23% reduction in the rate of falls.(13)

In healthcare settings, fall prevention measures for elderly hospitalized patients include the use of low beds and bed alarms, fixed hospital bed brakes, maintaining a dry floor, bedside commodes, adjusting beds to the lowest position, providing assistance in the bathroom, accessible call lights, and using transfer devices. Educating both patients and their families about the importance of fall prevention is crucial. Combining these prevention strategies, tailored to individual risk factors, is most effective in reducing fall risk. Collaborating with healthcare providers to identify specific risk factors and develop personalized fall prevention plans is highly recommended.(14)

Prior studies often lacked a clear framework for examining vestibular and somatosensory disturbances in older adults with balance disorders. This study addresses that gap by assessing 402 older adults using the Berg Balance Scale, m-CTSIB, and Modified Dix-Hallpike maneuver. This study provides insights

into how vestibular and somatosensory disturbances affect balance, enhancing the existing literature and informing future research. The findings suggest practical implications for developing rehabilitation strategies, improving health outcomes, and reducing healthcare costs for older adults with balance disorders.

Methods:

This cross-sectional study, based on a non-probability convenient sampling technique, included a sample size of 402 participants and was conducted over 12 months after obtaining approval from the Riphah International University's ethical committee. The ethical approval number is Riphah/RCRS/REC/01427. This cross-sectional design was chosen to analyze differences in balance performance by comparing vestibular and somatosensory systems while indicating fall risk by progressively challenging sensory systems, ultimately highlighting the importance of targeted rehabilitation strategies to address vestibular and somatosensory disturbances in older adults. The participants, aged 50 and above, had musculoskeletal co-morbidities and balance disorders assessed through the Berg Balance Scale (BBS). Exclusions comprised individuals with a history of neurological disorders, inner ear trauma, external auditory canal disease, spinal injury, and diabetes.

A total of 402 participants were recruited to enhance result authenticity, surpassing the required sample size of 377, with a 5% margin of error, 95% confidence level, and a response distribution of 50%. Data collection tools included the BBS, Modified Clinical Test of Sensory Interaction and Balance (m-CTSIB), and Modified-Dix-Hallpike Maneuver (m-DH). Various settings, including old age homes, hospitals, clinical OPDs in Rawalpindi and Islamabad, and door-to-door community visits, were accessed for data collection. Informed consent was obtained, and data confidentiality was maintained for research purposes. SPSS version 21 was used for data analysis.

The Berg Balance Scale (BBS) is a widely used 14-item tool for assessing balance and fall risk in the geriatric population. It categorizes items into sitting, standing, and dynamic balance, utilizing equipment such as a ruler, chairs, footstool, stopwatch, and a 15-ft walkway. Each item is scored on a 0-4 scale, with a total score ranging from 0 to 56. Fall risk classifications are as follows: 1) 41-56 = low fall risk, 2) 21-40 = medium fall risk, and 3) 0-20 = high fall risk.

The m-CTSIB evaluates sensory contributions to balance control, with patients performing four 30-second conditions: 1) Stand on a firm base with eyes open, 2) Stand on a firm base with eyes closed, 3) Stand on a foam base with eyes open, and 4) Stand on a foam base with eyes closed. The average score of three trials is calculated, and if needed, two additional attempts are given for patients unable to maintain positions for 30 seconds. BPPV induces vertigo and spinning sensations. The Dix-Hallpike test (m-DH) observes participants' eyes for nystagmus, where up-beating and torsional indicate posterior canal BPPV. Lateral or anterior BPPV is suspected with lateral or downbeat nystagmus. The m-DH is the gold standard for diagnosing posterior canal BPPV with high sensitivity (94.92%) and good specificity (91.43%).

The data was analyzed using SPSS version 21. Descriptive analysis, employing cross-tabulation, was conducted to explore the relationship between gender and m-DH and BBS. Variables, including m-DH, m-CTSIB, and BBS, were subjected to descriptive analysis, providing frequencies with percentages. Chi-square analysis was utilized to examine the descriptive relationship between BBS and m-CTSIB. Multiple regression analysis was employed to predict the efficacy of sensory systems in terms of balance control and fall risk among participants in Twin Cities. A significance level of $P < 0.05$ was considered statistically significant for both Multiple Regression and Chi-square analyses. The results were presented using tables, graphs, and bar charts. The data was analyzed at 95% confidence interval.

Results:

The study included a total of 402 participants, comprising 190 (47.1%) males and 212 (52.6%) females, with a mean age of 60.28±9.37 years.

The descriptive analysis of the Modified Dix Hallpike(m-DH) maneuver as shown in table 1 revealed 296 (73.4%) positive and 106 (26.3%) negative results. The Berg Balance Scale categorized participants into three risk levels: low (199, 49.4%), moderate (183, 45.4%), and high (20, 5%) risk of falls as depicted in Table 2.

Table 3 displays the results of the multiple regression analysis for predicting fall risk among older adults using the Berg Balance Scale (BBS) and various conditions of the Modified Clinical Test of Sensory Interaction and Balance (m-CTSIB). The analysis showed that balance control significantly predicts fall risk, with standardized coefficients (B) and 95% confidence intervals (CI) for each m-CTSIB condition. The model was statistically significant, $F(4, 397) = 104.244$, $p < 0.0005$, with $R = 0.716$ and R^2

Table 1: Frequencies of Modified Dix-Hallpike(m-DH) Maneuver Among Patients

	Attributes	Frequency	Percent
Modified Dix Hallpike	**Positive**	296	73.4%
	Negative	106	26.3%
	Total	402	100%

Table 2: Frequencies of Berg Balance Scale (BBS) Among Patients.

	Categories	Frequency	Percent
Berg Balance Scale	Low risk of fall (41- 56)	199	49.4%
	Moderate risk of fall (21-40)	183	45.4%
	High risk of fall (0- 20)	20	5%

Table 3: Multiple Regression Test for Prediction of Fall Risk Among Patients.

	Un Standardized Coefficient (B)	Standardized Coefficient (B)	Lower Bound	Upper Bound	P Value	R	R^2
Total BBS	3.864		3.551	4.176	<0.05		
Categories* CTSIB condition 1	-0.326	-0.210	-0.455	-0.197	<0.05		
Categories* CTSIB condition 2	-0.176	-0.196	-0.291	-0.60	<0.05	0.716	0.512
Categories* CTSIB condition 3	-0.245	-0.263	-0.355	-0.134	<0.05		
Categories* CTSIB condition 4	-0.131	-0.189	-0.213	-0.048	<0.05		

= 0.512, indicating that 51.2% of the variation in fall risk is explained by the model. The multiple regression formula used was:

Fall Risk = β0 +β1 (BBS) + β2 (m-CTSIB Condition 1) + β3 (m-CTSIB Condition 2) + β4 (m-CTSIB Condition 3)

All m-CTSIB conditions significantly predicted fall risk ($p < 0.05$), demonstrating a robust level of prediction for fall risk based on balance control measures.

Discussion:

This study used multiple regression to explore the relationship between sensory system dependency, balance control, and fall risk in older adults. The results suggest

that, with aging, the vestibular system tends to be more compromised compared to the somatosensory system. Older adults heavily rely on the visual and somatosensory systems for maintaining balance, aligning with findings by Alcock et al. in 2018, which also observed impaired vestibular function with aging. Consequently, both somatosensory and visual systems negatively impact balance and stability in the elderly.(15)

Examining participants with a mean age of 60.28±9.37 years, this study found that 73.4% exhibited positive outcomes in the Modified Dix-Hallpike maneuver (m-DH), indicating balance-related issues and suggesting age-related deterioration in the vestibular system. Similarly, Nimmo et al. in 2021, studying 1,116 older adults, noted abnormalities in vestibular testing among individuals with balance-related problems, emphasizing the significant role of vestibular dysfunction in balance impairment in the elderly.(16)

Categorizing the geriatric population into low (49.4%), moderate (45.4%), and high (5%) fall risk based on the Berg Balance Scale (BBS), this study's findings align with those of Arshad et al. in 2022, who conducted an RCT with 16 elderly patients, categorizing 62.50% as low-risk, 31.25% as medium-risk, and 6.25% as high-risk based on their BBS scores.(17)

The correlation between the Berg Balance Scale (BBS) and the Modified Clinical Test of Sensory Interaction in Balance (m-CTSIB) was assessed using the Chi-square test of independence. Our participants' balance performance results from both tools revealed a mild positive significant correlation ($P < 0.05$). Specifically, BBS with condition 1 of m-CTSIB reported a value of 200.636 with a degree of freedom (Df) value of 4, while conditions 2, 3, and 4 reported values of 231.31, 230.877, and 152.264, with Df values of 4, 6, and 4, respectively. A prior study by Antoniadou et al. (2020) also demonstrated a positive correlation between m-CTSIB and mini-BESTest-GR ($r=0.652$, $p<0.001$) and identified moderate significance between the screening tools of BBS and m-CTSIB in assessing balance among community-dwelling older adult females.(18)

In examining the relationship between variables such as m-DH and gender, this study, encompassing 402 participants with a mean age of 60.28±9.37, revealed a higher prevalence of positive m-DH outcomes in females. Among the 190 males (47.1%), 44.30% reported negative results, while among the 212 females (52.6%), 55.70% reported positive m-DH outcomes. A previous study comparing clinical manifestations of patients with benign paroxysmal positional vertigo (BPPV) between older and younger age groups found that vertigo, particularly in females under 60, was a common symptom associated with positive Dix-Hallpike test results. The study emphasized the importance of follow-up and patient management to prevent recurrence and improve the quality of life.(19)

In this study examining the relationship between the Berg Balance Scale (BBS) scores and gender among healthy older adults, three fall risk categories (low, moderate, and high) were evaluated. In the male group, which comprised 47.1% of the total participants (190 individuals), 54.80% reported a low risk of fall, 37.70% reported a moderate risk, and 60% reported a high risk. Conversely, in the female group, which comprised 52.6% of the total participants (212 individuals), 45.20% reported a low risk of fall, 62.30% reported a moderate risk, and 40% reported a high risk. With a mean age of 60.28±9.37 years, the findings suggest that males are more likely to be at low risk of falling, while females are more prone to moderate fall risk, indicating greater balance issues in women. Similarly, a study by Beauchamp et al. (2022) analyzing baseline data from an ongoing trial to prevent falls in people with COPD revealed significant gender differences in balance outcomes. Women with COPD demonstrated lower confidence in balance-related activities, worse overall balance, and lower scores on various balance assessment subcategories compared to men.(16)

The study has limitations, including a lack of diversity in the sample size and population, limiting the generalizability of findings to other groups. The use of a comparative cross-sectional methodology at a specific time makes it challenging to identify trends and relationships over time. Measurement bias may arise from subjective tests assessing vestibular and somatosensory disturbances, potentially lacking sensitivity for detecting subtle differences. The study did not consider confounding factors such as medication use, musculoskeletal injuries, hypertension, cardiovascular issues, psychological status, nutritional status, and family support.

Recommendations include objective assessments of sensory function, including vestibular function testing, sensory organization tests, biodex balance system, and computerized dynamic posturography, which should be integrated into research endeavors. To enhance statistical power and generalizability, future studies should aim for larger sample sizes

and diverse populations, encompassing different racial, and socioeconomic backgrounds, and geographical locations. Longitudinal and intervention studies focusing on somatosensory and vestibular abnormalities can offer insights into their crucial roles in balance disorders. Public awareness campaigns on factors contributing to falls among the elderly can be instrumental, especially in reducing treatment costs for economically disadvantaged individuals who may not afford expensive interventions for fall-related injuries. A comprehensive multimodal assessment strategy, incorporating subjective accounts, clinical assessments, and empirical data, will contribute to a more precise understanding of balance-related issues.

Conclusion:

The study found vestibular dysfunction prevalent in older adults. A mild positive correlation between the Berg Balance Scale and m-CTSIB indicates that sensory dependency impacts balance performance. As conditions progressed from 1 to 4, turning off sensory systems incrementally increased balance challenges and fall risk. In condition 1, all sensory systems were active, showing low fall risk with high BBS scores. By condition 4, somatosensory and visual systems were off on a dynamic surface, showing the highest fall risk with the lowest BBS scores, relying solely on the vestibular system. These results underscore the need for targeted rehabilitation to address vestibular and somatosensory disturbances, improving balance and health outcomes for older adults.

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Conflict of Interest: None to declare

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Authors Contribution

Khalid A: Conception of idea, Protocol writing, Data collection, Data analysis, Manuscript writing, Manuscript review

Ammar A: Conception of idea, Protocol writing, Data collection, Data analysis, Manuscript writing

Saqib A: Data collection, Data analysis, Manuscript writing

Ahmed W: Data collection, Data analysis, Manuscript writing

Safdar N: Data analysis, manuscript writing, Manuscript review

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