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Effect of Vestibular Stimulation on Balance and Cognitive Function Among Elderly Individuals in a Tertiary Care Hospital in North India

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ABSTRACT

Background: Age-related decline in balance and cognition significantly contributes to increased fall risk and reduced quality of life among the elderly. The vestibular system plays a crucial role in maintaining postural stability and has emerging links with cognitive processes. Vestibular stimulation has been proposed as a potential intervention to improve these functions.

Objectives: To evaluate the effect of vestibular stimulation on balance and cognitive function among elderly individuals and to determine the association between improvements in these domains.

Methods: A prospective interventional study was conducted among 146 elderly participants aged ≥60 years in a tertiary care hospital in North India from April to July 2017. Baseline assessment of balance and cognition was performed using the Berg Balance Scale (BBS) and Mini-Mental State Examination (MMSE), respectively. Participants underwent a structured vestibular stimulation program for four weeks. Post-intervention assessments were conducted using the same tools. Statistical analysis was performed using SPSS version 20.0, and paired t-test was applied to compare pre- and post-intervention scores. A p-value <0.05 was considered statistically significant.

Results: The mean BBS score improved significantly from 41.2 ± 6.5 to 46.8 ± 5.9 ($p<0.001$), indicating enhanced balance. Similarly, MMSE scores showed a significant increase from 24.1 ± 3.2 to 26.3 ± 2.8 ($p<0.001$), reflecting improved cognitive function. Greater improvements in balance were observed among younger elderly participants (60–69 years) compared to older age groups ($p=0.02$). A moderate positive correlation ($r=0.42$, $p<0.001$) was found between improvements in balance and cognition.

Conclusion: Vestibular stimulation significantly improves both balance and cognitive function in elderly individuals and may serve as an effective, non-invasive intervention in geriatric care. Its integration into routine rehabilitation programs could help reduce fall risk and enhance functional independence.

Keywords: Vestibular stimulation; Balance; Cognition; Elderly; Berg Balance Scale; Mini-Mental State Examination; Geriatric rehabilitation

Introduction

Population ageing is a global phenomenon, with a rapidly increasing proportion of individuals aged 60 years and above, particularly in low- and middle-income countries. Ageing is commonly associated with a decline in multiple physiological systems, including sensory, motor, and cognitive domains, which collectively contribute to reduced functional independence and quality of life [1]. Among these, impairments in balance and cognition are major contributors to falls, disability, and morbidity in the elderly population [2]. Falls are a leading cause of injury-related mortality and are often linked to deficits in postural control and vestibular dysfunction [3].

The vestibular system plays a crucial role in maintaining balance, spatial orientation, and postural stability. It integrates sensory inputs from the inner ear, visual system, and proprioceptive pathways to coordinate motor responses necessary for equilibrium [4]. With advancing age, structural and functional changes occur in the vestibular apparatus, including degeneration of hair cells and reduced neural conduction, leading to compromised balance and increased fall risk [5]. In addition to its role in balance, emerging evidence suggests that the vestibular system is closely linked to higher cognitive functions such as spatial memory, attention, and executive processing [6]. Vestibular inputs have been shown to influence hippocampal activity, a region critical for memory and navigation, thereby indicating a potential role in cognitive health [7].

Vestibular stimulation, which involves controlled activation of the vestibular system through specific physical or mechanical interventions (e.g., head movements, balance exercises, or caloric stimulation), has been explored as a therapeutic modality to enhance balance and cognitive function. Studies have demonstrated that vestibular rehabilitation can significantly improve postural stability and reduce fall risk in older adults [8]. Furthermore, preliminary research indicates that vestibular stimulation may enhance cognitive performance by improving neural plasticity and cortical integration [9]. Despite these promising findings, the extent of its combined effect on both balance and cognition remains inadequately explored, particularly in elderly populations from developing regions.

In the Indian context, the burden of age-related balance disorders and cognitive decline is increasing due to demographic transition and limited access to geriatric rehabilitation services. Cultural, environmental, and healthcare disparities further influence the prevalence and management of these conditions [10]. However, there is a paucity of structured clinical studies evaluating the effectiveness of vestibular stimulation interventions in improving both balance and cognitive outcomes among elderly individuals in North India, especially within tertiary care settings.

Given this background, there exists a significant research gap in understanding the dual impact of vestibular stimulation on balance and cognitive functions in the elderly population in this region. Addressing this gap is essential for developing cost-effective, non-invasive, and scalable interventions that can be integrated into geriatric care practices.

The present study aims to evaluate the role of vestibular stimulation in improving balance and cognitive function among elderly individuals attending a tertiary care hospital in North India. The objectives are to assess changes in balance performance and cognitive scores following a structured vestibular stimulation program and to determine the association between vestibular intervention and functional outcomes in this population.

Methodology

Study Design:A hospital-based prospective interventional study was conducted to evaluate the effect of vestibular stimulation on balance and cognitive function among elderly individuals.

Study Setting: The study was carried out in the Department of Physiology in collaboration with the Geriatric Medicine Unit of a tertiary care hospital in North India.

Study Duration: The study was conducted from April 2017 to July 2017.

Study Population: The study population comprised elderly individuals aged 60 years and above attending the outpatient department (OPD) and geriatric clinic of the tertiary care hospital during the study period.

Inclusion Criteria: Participants aged ≥60 years; both males and females; individuals able to ambulate independently or with minimal assistance; those willing to participate and provide written informed consent; and individuals with mild to moderate balance impairment or subjective cognitive complaints.

Exclusion Criteria: Individuals with diagnosed neurodegenerative disorders (e.g., Parkinsonism, advanced dementia); severe visual or auditory impairment interfering with assessment; history of recent stroke or acute neurological illness; severe musculoskeletal disorders limiting mobility; unstable cardiovascular conditions; current use of vestibular suppressants; and those unwilling to participate.

Sample Size : The sample size was calculated based on an expected moderate effect size in improvement of balance scores following vestibular stimulation, with a confidence level of

95% and power of 80%. Using the formula for comparison of means in paired observations:

$$n = \frac{(Z_{\alpha/2} + Z_{\beta})^2 \times \sigma^2}{d^2}$$

where ($Z\alpha2$= 1.96) for 95% confidence, ($Z\beta$ = 0.84) for 80% power, σ represents the standard deviation from prior studies, and (d) is the expected mean difference. Based on these assumptions and feasibility within the study duration, a sample size of 146 participants was finalized.

Sampling Technique:A consecutive sampling technique was employed, wherein all eligible participants attending the OPD during the study period were screened and recruited until the required sample size was achieved.

Data Collection Tools & Procedure: Data were collected using a structured proforma including demographic details and clinical history. Baseline assessment of balance was performed using the Berg Balance Scale (BBS), a validated tool for measuring functional balance in elderly individuals. Cognitive function was assessed using the Mini-Mental State Examination (MMSE). Following baseline evaluation, participants underwent a structured vestibular stimulation program consisting of supervised exercises such as head movements, gaze stabilization, and balance training, conducted for 20–30 minutes per session, five days a week, for four weeks. Post-intervention assessments were conducted using the same tools (BBS and MMSE) under standardized conditions.

Study Variables: The independent variable in this study was the vestibular stimulation intervention. The dependent variables included balance performance measured by BBS scores and cognitive function measured by MMSE scores. Additional variables such as age, gender, and comorbidities were considered as potential confounders and were recorded for analysis.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) version 25.0. Descriptive statistics were expressed as mean ± standard deviation for continuous variables and proportions for categorical variables. Pre- and post-intervention comparisons were performed using paired t-test for normally distributed data. Association between variables was assessed using appropriate correlation tests. A p-value of less than 0.05 was considered statistically significant.

Ethical Considerations: Written informed consent was obtained from all participants prior to enrollment. The study adhered to the ethical principles outlined in the Declaration of Helsinki. Confidentiality of participant information was strictly maintained, and participants were assured of their right to withdraw from the study at any stage without any consequences.

Results

A total of 146 elderly participants were included in the study, with the majority belonging to the 60–69 years age group and a slight male predominance. More than half of the participants had at least one comorbidity (Table 1)

Table 1: Socio-demographic characteristics of study participants (n = 146)

Variable	Category	Frequency (n)	Percentage (%)
Age (years)	60–69	64	43.8
	70–79	52	35.6
	≥80	30	20.5
Gender	Male	78	53.4
	Female	68	46.6
Residence	Urban	82	56.2
	Rural	64	43.8
Comorbidities (any)	Present	88	60.3
	Absent	58	39.7

There was a statistically significant improvement in balance following vestibular stimulation, as evidenced by an increase in mean Berg Balance Scale scores post-intervention (Table 2)

Table 2: Baseline and post-intervention balance scores (Berg Balance Scale)

Parameter	Mean ± SD	Mean Difference	p-value
Pre-intervention BBS	41.2 ± 6.5	5.6	<0.001*
Post-intervention BBS	46.8 ± 5.9		

*Statistically significant

Similarly, cognitive function showed significant enhancement, with higher post-intervention MMSE scores compared to baseline (Table 3)

Table 3: Baseline and post-intervention cognitive scores (MMSE)

Parameter	Mean ± SD	Mean Difference	p-value
Pre-intervention MMSE	24.1 ± 3.2	2.2	<0.001*
Post-intervention MMSE	26.3 ± 2.8		

*Statistically significant

Age-wise analysis revealed that younger elderly participants (60–69 years) demonstrated greater improvement in balance compared to older age groups, with the difference being statistically significant (Table 4)

Table 4: Association between age group and improvement in balance scores

Age Group (years)	Mean Improvement in BBS (± SD)	p-value
60–69	6.2 ± 2.1	0.02*
70–79	5.4 ± 2.3	
≥80	4.5 ± 2.0	

*Statistically significant

Furthermore, a moderate positive correlation was observed between improvements in balance and cognitive scores, indicating that participants who showed better balance outcomes also tended to exhibit greater cognitive improvement (Table 5).

Table 5: Correlation between improvement in balance and cognition

Variables Compared	Correlation Coefficient (r)	p-value
BBS improvement vs MMSE improvement	0.42	<0.001*

*Statistically significant

Discussion

The present study evaluated the effect of vestibular stimulation on balance and cognitive function among elderly individuals attending a tertiary care hospital in North India. The findings demonstrated a statistically significant improvement in both balance (as measured by Berg Balance Scale) and cognitive performance (as assessed by MMSE) following a structured vestibular stimulation program. Additionally, a moderate positive correlation between improvements in balance and cognition was observed, suggesting an interrelated mechanism underlying these functional domains.

The improvement in balance observed in this study is consistent with previous research highlighting the effectiveness of vestibular rehabilitation in enhancing postural stability and reducing fall risk among older adults. McDonnell and Hillier [8] reported that vestibular rehabilitation significantly improves balance outcomes in individuals with vestibular dysfunction, supporting the present findings. Similarly, Horak [4] emphasized the importance of sensory integration, particularly vestibular input, in maintaining postural equilibrium. The observed increase in BBS scores in our study indicates that targeted vestibular stimulation may enhance neuromuscular coordination and sensory processing, thereby improving functional balance.

The significant improvement in cognitive scores aligns with emerging evidence suggesting a link between vestibular function and higher cortical processes. Smith [6] described the vestibular system as an important contributor to cognitive domains such as attention and spatial memory. Furthermore, Brandt et al. [7] demonstrated that vestibular dysfunction is associated with hippocampal atrophy and impaired spatial memory, indicating a neuroanatomical basis for vestibular-cognitive interaction. The observed increase in MMSE scores in our study may be attributed to enhanced neural plasticity and improved cortical integration resulting from repeated vestibular stimulation. These findings are also supported by Smith et al. [9], who reported improved spatial working memory following non-invasive vestibular stimulation.

The age-wise analysis in the present study revealed that younger elderly participants (60–69 years) showed greater improvement in balance compared to older age groups. This may be explained by relatively preserved neural adaptability and musculoskeletal function in the younger subset of the elderly population. Age-related degeneration of sensory systems and reduced neuroplasticity in advanced age may limit the extent of functional recovery despite intervention [5]. This trend underscores the importance of early initiation of rehabilitative strategies in the ageing population.

The moderate positive correlation between improvements in balance and cognition observed in this study further supports the concept of shared neural pathways and integrative processing between vestibular and cognitive systems. Vestibular inputs are known to influence cortical regions involved in spatial orientation and executive functions, suggesting that enhancement of vestibular activity may have broader cognitive benefits [6]. This relationship highlights the potential of vestibular stimulation as a dual-benefit intervention in geriatric care.

From a clinical and public health perspective, the findings of this study are particularly relevant in the Indian context, where the ageing population is rapidly increasing and access to specialized geriatric rehabilitation services remains limited. Vestibular stimulation represents a low-cost, non-invasive, and easily implementable intervention that can be incorporated into routine physiotherapy and community-based programs. Its dual impact on balance and cognition makes it a valuable strategy for reducing fall risk and improving overall functional independence among elderly individuals.

The strengths of the present study include its prospective interventional design, use of standardized and validated assessment tools, and focus on a relatively understudied population in North India. However, certain limitations must be acknowledged. The study lacked a control group, which limits the ability to establish causality. The short duration of intervention and follow-up may not reflect long-term sustainability of the observed benefits. Additionally, the use of MMSE, while widely accepted, may not capture subtle cognitive changes across all domains. Future studies with randomized controlled designs, larger sample sizes, and longer follow-up periods are recommended to validate and extend these findings.

Conclusion

The present study demonstrates that vestibular stimulation is an effective intervention for improving both balance and cognitive function among elderly individuals. Significant improvements were observed in Berg Balance Scale and Mini-Mental State Examination scores following a structured four-week vestibular stimulation program. The positive correlation between balance and cognitive improvements suggests an interconnected mechanism, highlighting the broader neurological impact of vestibular inputs.These findings underscore the potential of vestibular stimulation as a simple, non-invasive, and cost-effective therapeutic approach that can be integrated into geriatric rehabilitation programs. Early implementation, particularly in younger elderly populations, may yield greater functional benefits and help reduce the risk of falls and cognitive decline.

Further research with randomized controlled designs and longer follow-up is recommended to establish long-term efficacy and generalizability. Incorporating vestibular-based interventions into routine clinical practice could contribute significantly to improving quality of life and functional independence in the ageing population.

Declarations

Funding: None.

Conflict of Interest: The authors declare no conflict of interest.

Ethical Approval: The study was approved by the Institutional Ethics Committee (IEC) of the tertiary care hospital.

Consent: Written informed consent was obtained from all participants prior to enrollment.

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