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Influence Of Visual And Auditory Deprivation On Sway Amplitude

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Abstract

Background
Postural control depends on the integration of visual, vestibular, and somatosensory systems. Alteration in sensory input may influence balance and sway amplitude.
Objective: To determine the influence of visual and auditory deprivation on sway amplitude in young healthy adults.
Methods: An observational study was conducted among 98 participants aged 17–25 years using convenience sampling at JSS College of Physiotherapy, Mysuru. Postural sway was assessed under three conditions: eyes open (EO), auditory deprivation (AD), and visual deprivation (VD). Participants were made to stand for one minute while sway was recorded using two high-resolution cameras in anterior and lateral views. Analysis was performed using Kinovea software. Repeated measures ANOVA was used for statistical analysis with significance set at $p < 0.05$.
Results: A significant increase in sway amplitude was observed during visual deprivation compared to eyes open and auditory deprivation. Anterior sway (2.66 ± 1.372) and latero-medial sway (1.99 ± 1.125) were highest in visual deprivation ($p < 0.001$). Posterior sway also increased under visual deprivation (0.43 ± 0.699; $p < 0.003$). No significant difference was observed between eyes open and auditory deprivation across all directions.
Conclusion: Visual deprivation significantly affects postural stability, whereas auditory deprivation has minimal influence. Vision plays a dominant role in balance control, highlighting the importance of sensory integration in maintaining postural stability.

Keywords: Postural control; Sway amplitude; Visual deprivation; Auditory deprivation; Balance; Sensory integration; Young adults; Postural stability

INTRODUCTION

Postural control is defined as the act of maintaining, achieving or restoring a state of balance during any posture or activity. The basis of motor performance is to control postural stability under different internal and external conditions. Posture control is manifested by body sway connected with visual, proprioceptive, vestibular and auditory stimuli. Because the phonoreceptors and the vestibular organ are situated anatomically close to each other, sound vibrations can influence posture control. The auditory organ, which is morphologically and functionally mutually connected with the vestibular system, receives sound stimuli in the form of a wave of air density disturbances which affects the vestibular system as well and in general postural control [1].

Vision plays a dominant role in postural control by providing spatial orientation and environmental feedback. Visual input helps in detecting body position relative to surroundings and contributes significantly to reducing postural sway. Studies have demonstrated that removal of visual cues, such as closing the eyes, results in a marked increase in sway amplitude, highlighting the dependence of balance on visual information [2, 3]. This phenomenon is particularly evident in challenging postural conditions or among individuals with compromised proprioceptive or vestibular function.

In contrast, the role of auditory input in postural control has received comparatively less attention. However, emerging evidence suggests that auditory cues contribute to spatial awareness and orientation, thereby indirectly influencing balance. Auditory information, particularly environmental sounds and spatial hearing, can provide reference points that assist in stabilizing posture. Deprivation of auditory input has been associated with subtle but measurable changes in postural sway, indicating its supportive role in sensory integration [4, 5].

The central nervous system continuously reweights sensory inputs depending on their availability and reliability, a process known as sensory reweighting. When one sensory modality is compromised, such as vision or hearing, the body compensates by relying more heavily on the remaining inputs. However, simultaneous deprivation of multiple sensory systems may significantly impair balance control and increase sway amplitude, thereby elevating the risk of instability and falls [6].

Balance is an even distribution of weight enabling someone to remain upright and steady. Maintaining balance is known to be a multisensory process that uses information from different sensory organs, it requires the integration of vestibular, proprioceptive and visual information and the translation of this into appropriate motor responses[7, 8].

Understanding the individual and combined effects of visual and auditory deprivation on sway amplitude is essential for developing targeted rehabilitation strategies, particularly in populations with sensory deficits. This knowledge has important implications in physiotherapy, fall prevention, and neurorehabilitation, where enhancing sensory integration can improve postural stability and functional outcomes.

Commonly used methods for assessing postural sway are the tandem Romberg test and the Fukuda stepping test, posturography, force plates, Nintendo Wii gaming console and balance board, video recording etc[7-9].

NEED FOR THE STUDY

Standardised methods of assessing postural sway such as force plates, Nintendo Wii are very expensive and complicated to use at clinical setup. Hence the need arises to use simple method such as video recording to assess influence of visual and auditory deprivation on sway amplitude.

Clinical significance
Use of simpler and relatively faster analysis of postural sway by video recording in patients with balance disorders.

AIM AND OBJECTIVES OF THE STUDY

To assess the sway amplitude in frontal and saggital view in normal individual by video recording-1) with eyes open
2) with vision deprivation
3) with auditory deprivation

Methodology
Study Design and Setting
This observational study was conducted at JSS College of Physiotherapy, Mysuru, over a period of two months in a controlled and quiet laboratory environment to ensure minimal external sensory interference during testing.

Sample Size and Sampling Technique
A total of 98 participants were recruited using a convenience sampling technique. The sample size was determined using the formula:
$n = 2 (Z\alpha + Z\beta)^2 (SD^2 / d^2)$, where $Z\alpha = 1.96$, $Z\beta = 0.84$, standard deviation (SD) = 2, and effect size (d) = 5.

Participants
Participants included male and female individuals aged between 17 and 25 years who voluntarily agreed to participate in the study.

Inclusion Criteria

- Individuals aged 17–25 years
- Both males and females
- Willingness to participate

Exclusion Criteria

- History of hearing or vestibular impairments
- Limb length discrepancy greater than 2 cm
- Presence of any lower limb orthopedic condition
- Diagnosed visual or balance disorders

Ethical Considerations
Ethical approval for the study was obtained from the Institutional Ethical Committee of JSS College of Physiotherapy, Mysuru. All participants provided written informed consent prior to participation. The study adhered to the principles outlined in the Declaration of Helsinki for research involving human subjects.
Materials and Equipment

The instruments used for data collection included a stopwatch, measuring tape, two high-resolution cameras, Bluetooth headset, ear defenders, white noise audio, Kinovea software (version 0.8.15), a postural grid, two plumb lines, and colored tape for anatomical landmark identification.

Procedure
Participants were recruited from Bachelor and Master of Physiotherapy programs through advertisement. Following recruitment, participants underwent a screening process that included an interview to assess hearing, vision, and balance status, along with limb length measurements. Individuals not meeting the eligibility criteria were excluded.

Eligible participants were assessed in a quiet and controlled environment. Each participant was instructed to stand upright in front of a postural grid with feet placed parallel at hip-width and arms relaxed by the sides. A plumb line was aligned along the midline of the body for anterior reference, and a second plumb line was used for lateral alignment.

Postural sway was evaluated under three sensory conditions: (1) eyes open, (2) visual deprivation, and (3) auditory manipulation. Visual deprivation was achieved using a blindfold. Auditory input was manipulated using Bluetooth earphones delivering white noise, while ear defenders were used to minimize external auditory cues. Each participant maintained a static standing posture for one minute under each condition.

Simultaneous video recordings were obtained in anteroposterior and lateral views using two high-resolution cameras. Anatomical landmarks including the forehead, acromion process, styloid process, anterior superior iliac spine (ASIS), lateral femoral condyle, lateral malleolus, and fifth metatarsal were marked using colored tape to facilitate motion analysis.

Outcome Measures
Sway amplitude was quantified using Kinovea software (version 0.8.15). In the anterior view, angular displacement was measured relative to a vertical reference (plumb line), using the forehead as the primary reference point. In the lateral view, alignment was assessed using the external auditory meatus (EAM), acromion, greater trochanter, knee joint, and lateral malleolus. Sway amplitude was calculated as the angular deviation from the vertical reference line in both anterior–posterior directions.

Statistical Analysis
Data analysis was performed using the Statistical Package for the Social Sciences (SPSS) software, version 23. Descriptive statistics, including mean and standard deviation, were calculated to summarize participant characteristics and sway amplitude across different testing conditions.
The normality of data distribution was assessed using the Shapiro–Wilk test. Inferential analysis was conducted using repeated measures analysis of variance (ANOVA) to evaluate differences in sway amplitude under various sensory conditions (eyes open, visual deprivation, and auditory manipulation). Where significant differences were identified, post hoc comparisons with Bonferroni correction were applied to determine pairwise differences between conditions. The level of significance was set at $p < 0.05$

Results

Data analysis was performed using SPSS version 23. Postural sway was assessed under three sensory conditions—eyes open (EO), auditory deprivation (AD), and visual deprivation (VD)—across anterior, posterior, and latero-medial directions. Results are presented as mean ± standard deviation (SD), and comparisons were made using repeated measures ANOVA.

Table I: Anterior Sway

	Mean ±Standard Deviation	Significance
EOAS	1.21±.639	<0.01
ADAS	1.29±.745	
VDAS	2.66±1.372	

Table I shows mean and SD in anterior sway with eyes open, auditory deprivation and visual deprivation with p value (<0.00) which is done using the repeated measures ANOVA test.

Anterior Sway

As shown in Table I, the mean anterior sway was 1.21 ± 0.639 in the eyes-open condition, 1.29 ± 0.745 during auditory deprivation, and markedly increased to 2.66 ± 1.372 during visual deprivation. The difference across conditions was statistically significant ($p < 0.001$). Visual deprivation demonstrated a substantial increase in anterior sway compared to both eyes open and auditory deprivation, while minimal difference was observed between the latter two conditions.

TABLE II: Posterior sway

	Mean ± Standard Deviation	Significance
EOPS	.16±.402	<0.003
ADPS	.16±.367	
VDPS	.43±.699	

Table II shows mean and SD in posterior sway in eyes open , auditory deprivation and visual deprivation with p value (<0.003) which is done using repeated measures ANOVA test.

Posterior Sway

In Table II, posterior sway values were 0.16 ± 0.402 (EO), 0.16 ± 0.367 (AD), and 0.43 ± 0.699 (VD). A statistically significant difference was observed among the conditions ($p < 0.003$). Although posterior sway increased during visual deprivation, the magnitude of change was smaller compared to anterior and latero-medial directions. Eyes open and auditory deprivation conditions showed nearly identical sway values.

TABLE III: Latero-medial Sway

	Mean ±Standard Deviation	Significance
EOLMS	1±.000	<0.01
ADLMS	0.87±.442	
VDLMS	1.99±1.125	

Table III shows mean and SD in latero-medial sway in eyes open , auditory deprivation and visual deprivation with p value (<0.00) which is done using repeated measures ANOVA test.

Latero-Medial Sway

As presented in Table III, latero-medial sway was 1.00 ± 0.000 in the eyes-open condition, 0.87 ± 0.442 during auditory deprivation, and significantly increased to 1.99 ± 1.125 during visual deprivation. The differences were statistically significant ($p < 0.001$). Visual deprivation resulted in the highest sway amplitude, while auditory deprivation showed a slight reduction compared to eyes open.

Overall Findings

The results indicate that visual deprivation significantly increases postural sway, particularly in the anterior and latero-medial directions. Posterior sway also increased under visual deprivation, though to a lesser extent. In contrast, auditory deprivation showed minimal impact on sway amplitude when compared to the eyes-open condition across all directions. These findings suggest that visual input plays a dominant role in maintaining postural stability, whereas auditory input has a comparatively limited influence.

Discussion

This study was designed to determine the influence of visual and auditory deprivation on sway amplitude in young healthy adults aged between 17 and 25 years. The primary objective was to evaluate the extent to which postural sway is affected by the absence of visual and auditory inputs using a relatively simple and time-efficient analysis method.

The findings of the present study indicate that postural stability is significantly improved in the presence of visual input, as observed in both the eyes-open and auditory deprivation conditions. This can be attributed to the role of the visual system in providing continuous feedback to the central nervous system regarding body position in relation to the surrounding environment. Visual cues enhance spatial orientation and allow for anticipatory and corrective postural adjustments, thereby reducing sway amplitude. These findings are consistent with previous research by Palm HG et al., which reported significant differences in postural stability between eyes-open and eyes-closed conditions.

In contrast, no significant difference was observed between the eyes-open and auditory deprivation conditions in the present study. This suggests that auditory input alone may not play a primary role in maintaining postural stability in healthy individuals. The preserved visual and somatosensory inputs in these conditions may have compensated effectively for the absence of auditory cues. As balance control is a multisensory process, deprivation of a single non-dominant sensory system may not significantly disrupt postural equilibrium, particularly in young adults with intact sensory systems.

Although auditory input is not considered as critical as visual, vestibular, or somatosensory inputs in postural control, it may still contribute to spatial orientation. Supporting this, Melo RS et al. reported that individuals with hearing impairment exhibited greater postural instability compared to those with normal hearing, indicating that auditory cues may have a supplementary role in balance regulation. However, the discrepancy between such findings and the present study may be due to differences in study populations, as individuals with chronic hearing loss may experience long-term sensory adaptation affecting postural control mechanisms.

The significant increase in sway amplitude observed during visual deprivation further emphasizes the dominant role of vision in balance maintenance. Both anterior and latero-medial sway showed marked increases under visual deprivation, indicating that visual input is essential for maintaining stability in multiple planes. Posterior sway also increased, though to a lesser extent, suggesting partial compensation by vestibular and proprioceptive systems. These findings support the theory of sensory reweighting, wherein the central nervous system dynamically adjusts reliance on available sensory inputs. When visual input is removed, the system attempts to rely more on vestibular and somatosensory information; however, this compensation may be insufficient, resulting in increased sway.

A potential limitation of this study is that complete auditory deprivation may not have been achieved, as participants could still perceive residual environmental sounds despite the use of ear defenders. Additionally, the study required multiple investigators for accurate data collection, including simultaneous video recording from anterior and lateral views and precise placement of anatomical markers, which may introduce inter-observer variability. Another limitation is that participants were aware of being observed for balance assessment, which may have influenced their postural control due to increased concentration or conscious correction of sway.

Furthermore, the concept of a true “control” condition in postural studies remains questionable. When individuals are aware that their balance is being assessed, their attentional focus may alter natural postural sway behavior. Increased cognitive engagement or conscious effort to maintain stability could potentially reduce sway, thereby influencing the results. This highlights the importance of considering attentional and cognitive factors in future postural control research.

From a clinical perspective, the findings of this study underscore the importance of visual input in maintaining balance and suggest that rehabilitation programs should incorporate visual challenges to enhance sensory integration. Training under altered sensory conditions may improve adaptability of the postural control system, which is particularly beneficial for individuals at risk of balance impairments.

Future Recommendations

Future studies should aim to include a larger and more diverse sample, including older adults and clinical populations, to improve generalizability. The use of more advanced tools such as force platforms or computerized dynamic posturography may provide more precise measurements. Additionally, investigating complete sensory deprivation conditions and incorporating cognitive dual-task paradigms may offer deeper insights into the mechanisms of postural control.

CONCLUSSION

The study concludes that visual deprivation has influence on sway amplitude more than auditory deprivation. The vestibular system receives from the auditory deprivation, however is weaker than that received from visual deprivation. The auditory deprivation does not have much influence on the postural control. Since postural control was regulated by multiple senses such as visual system, vestibular system and proprioception.

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Conflict of interest: The authors have declared that no conflict of interest exists.

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ANNEXURE: PHOTOS

Plate 1: Sway from midline

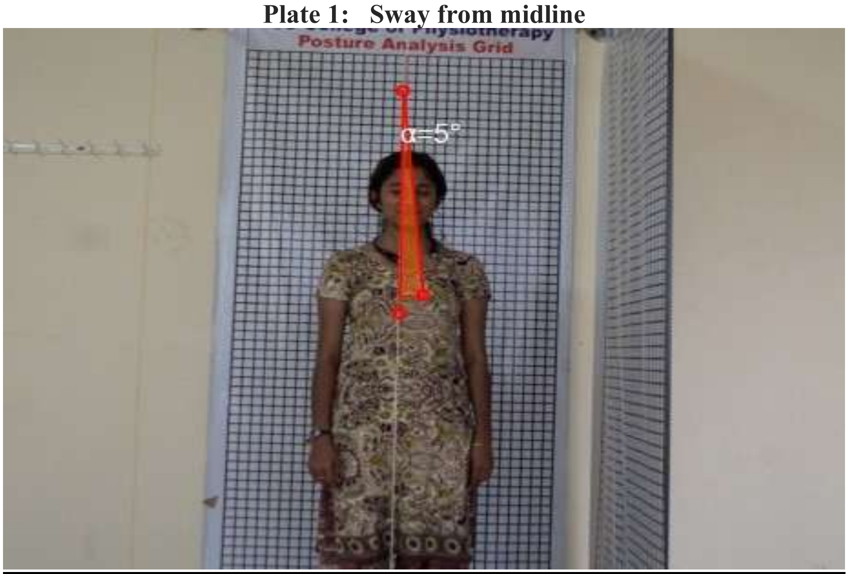

Plate 2: Measurement of sway from midline in anterior view taking reference as plumb line and forehead

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(putting red tape on forehead)

Plate 3: Sway from midline in lateral view

Plate 4: Measurement of sway from midline in lateral view taking reference as plumb line and EAM (Putting red tape)