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ASSOCIATION OF CERVICAL PROPRIOCEPTION AND BALANCE AMONG VESTIBULAR DYSFUNCTION PATIENTS; A CROSS-SECTIONAL STUDY

Original Research

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ABSTRACT

Background: Balance in humans relies on the integration of somatosensory, visual, and vestibular sensory systems, which work together to compensate for deficits in any one system. Vestibular disorders arise from pathologies affecting the vestibular apparatus in the middle ear or the central nervous system. Common symptoms include nystagmus, vertigo, imbalance, nausea, and headache, significantly impacting quality of life and postural stability.

Objective: To determine the association between cervical proprioception deficits and balance impairments among various vestibular dysfunctions, including benign paroxysmal positional vertigo (BPPV), Meniere's disease, unilateral vestibular dysfunction, and bilateral vestibular dysfunction.

Methods: This cross-sectional study included 71 participants selected through purposive sampling over a six-month period. Cervical proprioception was measured using the Cervical Joint Position Error Test (CJPET), while balance deficits were evaluated with the Berg Balance Scale (BBS). Participants were categorized into three risk levels based on BBS scores: low fall risk (51–56), moderate fall risk (40–50), and high fall risk (<40). Age, gender, and BMI data were recorded, and statistical analysis was conducted to identify correlations between cervical joint position errors in flexion, extension, and rotation with balance outcomes.

Results: The mean age of participants was 37.36 ± 7.35 years. Males constituted 64.8% of the sample, while females accounted for 35.2%. Most participants (81.6%) had normal BMI, 9.9% were underweight, and 8.5% were overweight. Significant correlations were found between balance impairments and cervical joint position errors in flexion ($p = 0.025$) and extension ($p = 0.039$), but no significant correlations were observed for left ($p = 0.590$) or right ($p = 0.421$) rotational movements.

Conclusion: Cervical proprioception deficits in flexion and extension movements are significantly associated with balance impairments in patients with vestibular dysfunctions, while rotational movements showed no significant relationship. These findings highlight the importance of targeting specific cervical movements in therapeutic interventions for balance disorders.

Keywords: Balance Disorders, Dizziness, Postural Balance, Proprioception, Vertigo, Vestibular Diseases, Vestibulo-Ocular Reflex.

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INTRODUCTION

Balance and orientation control in humans are maintained through a complex interplay of peripheral sensory inputs derived from the somatosensory, visual, and vestibular systems, which are then integrated by the central nervous system to generate coordinated motor responses. Accurate sensory feedback from these systems is critical for maintaining postural stability and equilibrium. The vestibular system, comprising the otolith organs and semicircular canals, relays impulses to the vestibular nuclei, where ascending and descending pathways facilitate communication with cranial nerves III, IV, and VI, as well as with the cerebellum. These pathways, including the medial longitudinal fasciculus, regulate eye movements and contribute to postural adjustments via the vestibulo-collic and vestibulospinal tracts (4). Cervical proprioception, specifically the sensory feedback originating from the cervical muscles and tendons, plays an essential role in detecting changes in head position and contributing to balance regulation, particularly in the context of impaired vestibular and visual cues (5, 6).

Vestibular dysfunction, characterized by symptoms such as vertigo, nystagmus, and postural instability, arises from impairments in the inner ear, central processing centers, or both. It is categorized into central and peripheral forms, with significant implications for patient well-being. Epidemiological studies reveal a prevalence of 4.9% over a one-year period and a lifetime incidence of 7.4%, with higher rates observed in women, older individuals, and those with cardiovascular conditions or depression (7, 8). Diagnosis relies on comprehensive history-taking, physical examination, and diagnostic testing, which collectively identify the underlying deficits (9). Research has highlighted the association between vestibular dysfunction and an increased risk of falls, particularly in older populations, underscoring the need to address balance-related deficits in this demographic (10, 11).

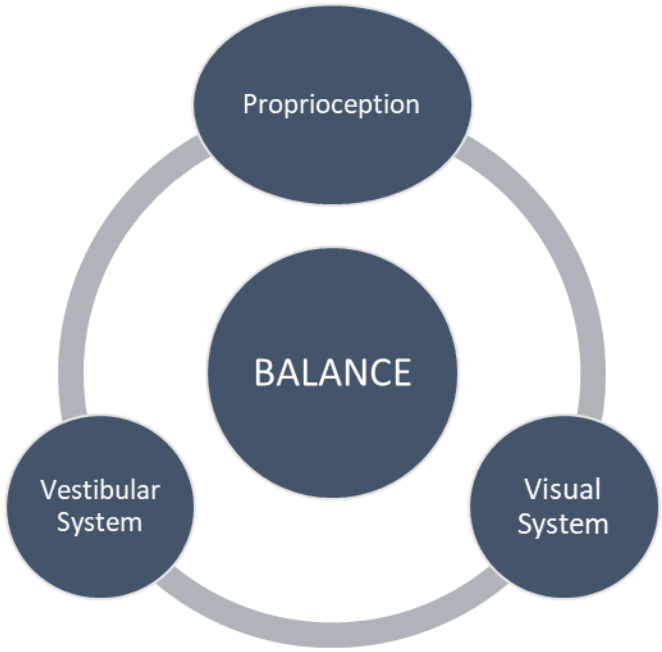

Figure 1 Components of Balance

Cervical proprioception emerges as a key player in mitigating balance deficits associated with vestibular dysfunction. Prior studies suggest that dynamic cervical proprioception significantly reduces head-trunk orientation errors, often outperforming vestibular and visual inputs in this regard (5). Moreover, cervical proprioception has been linked to neck pain and postural discrepancies under varying conditions, further highlighting its importance in balance and coordination (13, 14). The role of proprioceptive feedback is especially pronounced in individuals with bilateral vestibular failure, where it attenuates dynamic fluctuations in posture and head orientation (6).

Epidemiological insights into vestibular dysfunction have also demonstrated gender and age-related variations in prevalence, with women and older adults disproportionately affected. For instance, vertigo was diagnosed in 6.5% of surveyed cases, with women being significantly more prone to the condition (15). Furthermore, studies have identified varying degrees of proprioceptive error during different postures and movements, suggesting a nuanced interaction between cervical proprioception and external biomechanical factors (14).

Despite prior research, there remains a paucity of studies exploring the direct relationship between cervical proprioception deficits and balance impairments in patients with vestibular dysfunction. While previous investigations have examined these parameters in healthy individuals or isolated contexts, their applicability to clinical populations is limited. This study aims to bridge this gap by investigating the association between cervical proprioception deficits and balance dysfunction among patients with vestibular impairments, thereby contributing to a more comprehensive understanding of the interplay between sensory feedback mechanisms and postural control.

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METHODS

A cross-sectional study design was employed to investigate the association between cervical proprioception deficits and balance impairments among patients with vestibular dysfunction. Participants were selected using a purposive sampling technique, and a total of 71 individuals were included in the study. The inclusion criteria required participants to have a clinically confirmed diagnosis of vestibular dysfunction, while individuals with other neurological disorders, significant musculoskeletal impairments, or cognitive impairments that could influence balance assessments were excluded. Both genders were included, with participants aged 20 to 65 years, to ensure a broad representation of individuals with vestibular dysfunction.

The study was conducted over a six-month period, and two validated tools were used to assess the primary variables. Cervical proprioception was evaluated using the Cervical Joint Position Error Test (CJPET), a reliable method for assessing proprioceptive deficits by measuring the accuracy of head repositioning movements. Balance impairment was measured using the Berg Balance Scale (BBS), which classifies participants into three categories based on their scores: 56–50 indicating low fall risk, 51–40 moderate fall risk, and scores below 40 indicating high fall risk. These classifications provided a standardized approach to stratifying participants based on their risk of balance-related incidents.

To account for potential confounding variables, demographic information such as age, gender, and medical history was collected during the initial assessment. Efforts were made to ensure randomization in participant selection to minimize selection bias, although the use of purposive sampling may have introduced some limitations in generalizability. The sample comprised individuals from diverse socioeconomic backgrounds, aiming to reflect the variability in vestibular dysfunction presentations.

While the methodology adequately addressed the study's objectives, a notable limitation was the reliance on purposive sampling, which may limit the external validity of the findings. Moreover, the study design did not include a control group of healthy participants for comparison, which could have strengthened the conclusions. Nonetheless, the tools used for assessment, CJPET and BBS, are widely recognized for their reliability and validity in evaluating proprioceptive and balance deficits. The study's approach provided a robust framework for exploring the interplay between cervical proprioception and balance in individuals with vestibular dysfunction.

RESULTS

The results of the study revealed that the mean age of the participants was 37.36 ± 7.35 years, with a normal distribution observed in the age range. The gender distribution showed a predominance of males, comprising 64.8% of the sample, compared to females at 35.2%, indicating a slight gender imbalance in the study population. Regarding the body mass index (BMI), 81.6% of participants fell within the normal BMI range, 9.9% were underweight, and 8.5% were overweight. This demographic distribution highlights a relatively diverse sample, though skewed toward male participants with predominantly normal BMI values.

The analysis of the Berg Balance Scale (BBS) revealed that the majority of participants, 88.7% (63 individuals), scored between 51 and 56, reflecting a lower risk of falls, while 11.3% (8 individuals) scored between 40 and 50, indicating a moderate fall risk. Among the vestibular dysfunction diagnoses, vestibular migraine was the most frequent condition, accounting for 28.2% of the cases (20 individuals). Benign paroxysmal positional vertigo (BPPV) and Meniere's disease followed, with 21.1% (15 individuals) and 18.3% (13 individuals), respectively. Other conditions included vestibular proxysmia, semicircular canal dehiscence syndrome, and general vestibulopathy, each at 7.0% (5 individuals), while vestibular neuritis accounted for 5.6% (4 individuals). Unilateral and bilateral vestibular hypofunction were the least common, with 2.8% (2 individuals each) diagnosed in the study population.

Statistical analysis demonstrated significant positive correlations between cervical joint position error in flexion ($p < 0.001$) and extension movements ($p < 0.001$) with BBS scores, suggesting an association between cervical proprioceptive errors and balance performance. However, no significant correlations were observed for cervical joint position errors in left rotation ($p = 0.590$) and right rotation ($p = 0.421$). These findings emphasize the relevance of flexion and extension movements in cervical proprioceptive assessments for understanding balance impairments in vestibular dysfunction patients.

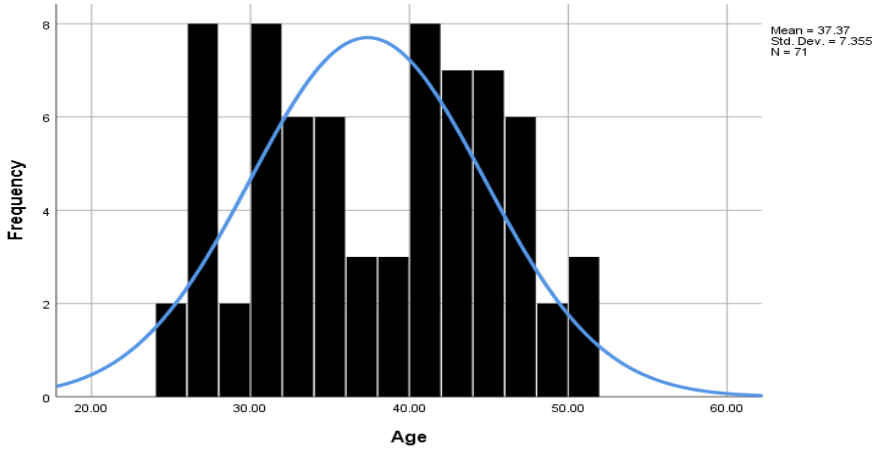

Figure 2 Age of Participants

The mean of age was 37.36±7.35 and graphical analysis shows normal histogram curve with no skewness.

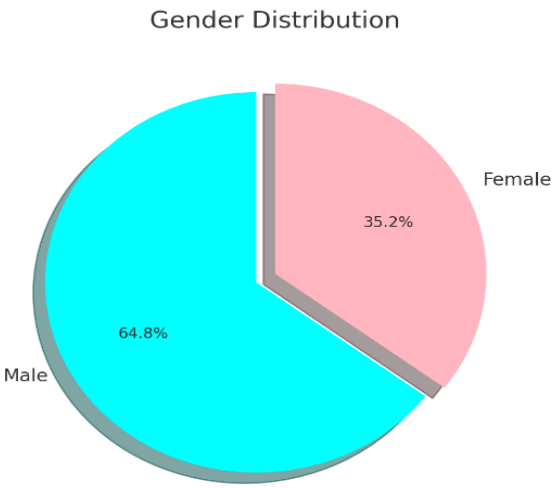

Figure 3 Gender

Pie chart shows the frequency rate of gender in vestibular dysfunction patients. In our study 46 were males and 25 were females, suggesting a higher representation of males in the sample population with a slight gender imbalance towards males.

Table 1 Vestibular Dysfunction Diagnoses

Diagnosis	Frequency	Percentage (%)
BPPV	15	21.1
Meniere's Disease	13	18.3

Diagnosis	Frequency	Percentage (%)
Vestibular Migraine	20	28.2
Vestibular Proxysmia	5	7.0
Unilateral Vestibular Hypofunction	2	2.8
Bilateral Vestibular Hypofunction	2	2.8
Vestibular Neuritis	4	5.6
Semicircular canal dehiscence syndrome	5	7.0
General Vestibulopathy	5	7.0
Total	71	100.0

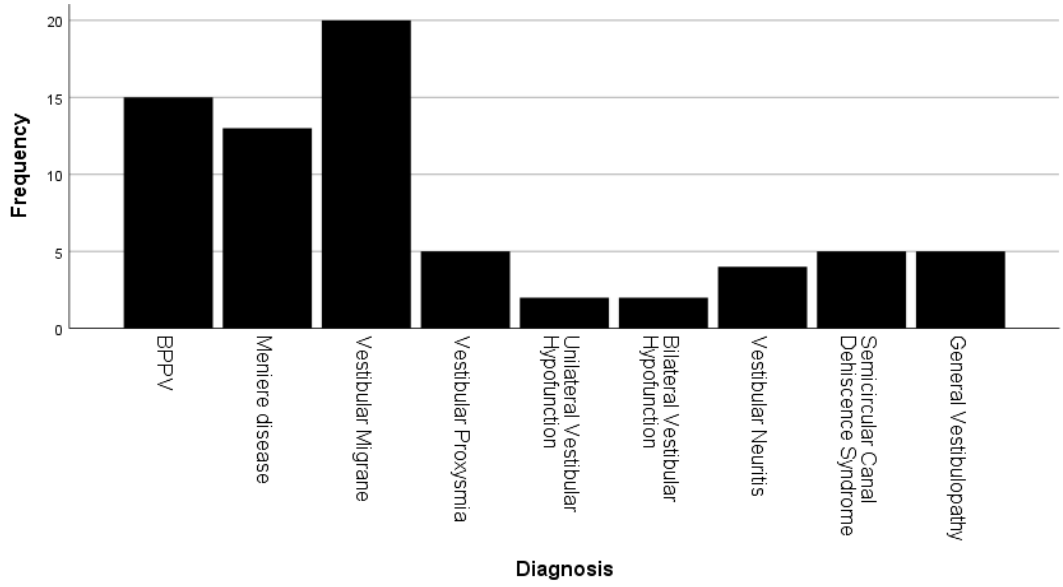

Figure 4 Vestibular Dysfunction Diagnoses

The study analyzed the distribution of vestibular dysfunction diagnoses among 71 participants, revealing that vestibular migraine was the most prevalent condition, accounting for 28.2% (20 individuals). Benign paroxysmal positional vertigo (BPPV) followed with 21.1% (15 individuals), and Meniere's disease accounted for 18.3% (13 individuals). Other conditions included vestibular proxysmia, semicircular canal dehiscence syndrome, and general vestibulopathy, each contributing 7.0% (5 individuals). Less common conditions were vestibular neuritis at 5.6% (4 individuals), and both unilateral and bilateral vestibular

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hypofunction, each at 2.8% (2 individuals). These findings highlight the diverse spectrum of vestibular dysfunctions encountered in the study population.

Table 2: Berg Balance Scale (BBS) Score

Berg balance scale	Frequency	Percentage(%)
40 – 50 (Moderate fall risk)	8	11.3
51 – 56 (Less fall risk)	63	88.7
Total	71	100.00

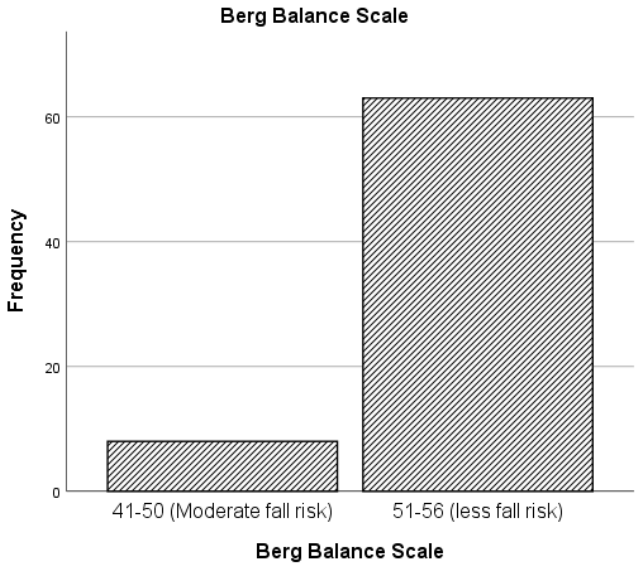

Figure 5 Berg Balance Scale (BBS) Score

In the data provided from the Berg Balance Scale assessment, it is evident that out of a total of 71 individuals assessed, 8 individuals (11.3%) fell within the category of moderate fall risk, scoring between 40 and 50 on the scale. The majority of participants, comprising 63 individuals (88.7%), demonstrated a lower fall risk level, scoring between 51 and 56 on the scale.

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Table 3: Correlation of Cervical Joint Position Error (Flexion) and Berg Balance Scale

Cervical joint Position Error (Flexion) and Berg Balance Scale	
Pearson Chi square	0.025
Sig. (p value)	<0.00
N	71
Cervical joint Position Error (Extension) and Berg Balance Scale	
Pearson Chi square	0.039
Sig. (p value)	<0.00
N	71
Cervical joint Position Error (Left Rotation) and Berg Balance Scale	
Pearson Chi square	0.590
Sig. (p value)	<0.00
N	71
Cervical joint Position Error (Right rotation) and Berg Balance Scale	
Pearson Chi square	0.421
Sig. (p value)	<0.00
N	71

The Pearson Chi-square tests indicated a statistically significant association between Cervical Joint Position Error in Flexion ($p < 0.001$) as well as Extension ($p < 0.001$) with the Berg Balance Scale scores among the 71 participants. However, for Cervical Joint Position Errors in Left Rotation ($p = 0.590$) and Right Rotation ($p = 0.421$), no significant association was found with the Berg Balance Scale scores. These results suggest that errors in cervical proprioception during flexion and extension movements are closely linked to balance abilities as assessed by the Berg Balance Scale, highlighting the importance of assessing specific joint position errors in relation to overall balance performance.

DISCUSSION

The findings of this study align with the established role of cervical proprioceptive receptors in maintaining coordination of head, eye, neck, and body movements through their integration with the vestibular and visual systems. Proprioceptive signals from the cervical spine are critical for ensuring postural control, and disruptions in this integration can contribute to cervicogenic dizziness and balance impairments. Previous studies have highlighted the potential for mismatches between vestibular, visual, and proprioceptive signals to alter cervical proprioceptive input, predisposing individuals to postural instability and fall risk (16). This physiological relationship was supported by the significant correlation observed in this study between cervical joint position errors during flexion and extension movements and balance performance, as assessed by the Berg Balance Scale.

The study provided further evidence that altered vestibular output, particularly in cases of acute vestibular dysfunction, can exacerbate cervical joint position errors. This association underscores the importance of addressing vestibular pathologies to mitigate cervical proprioceptive impairments. Prior research has suggested that reduced cervical range of motion and increased cervical joint position errors are predictive of higher fall risk, particularly in older adults (17, 18). Similarly, this study indicated that cervical proprioception,

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particularly in sagittal plane movements, plays a significant role in postural control, while rotational movements demonstrated less influence on overall balance outcomes.

The observed alterations in cervical kinematics, including decreased velocity and asymmetry, are consistent with findings in individuals with vestibular dysfunction. These kinematic abnormalities may contribute to cervical joint position errors, further impairing balance and postural stability. Additionally, overuse of posterior neck muscles in certain postures, such as sitting, may exacerbate neck proprioceptive inaccuracies, as suggested by prior studies and supported by the findings of this research (14, 19).

A recent comparative study investigated cervical proprioception and functional balance among elderly individuals with chronic neck pain (CNP) and asymptomatic individuals, revealing significant impairments in proprioception and balance in those with CNP. This cross-sectional study included 60 elderly individuals with CNP and 60 asymptomatic controls, measuring cervical joint position errors (JPE) in flexion, extension, and rotational directions, alongside balance assessments using the Berg Balance Scale (BBS) and Timed-Up-and-Go (TUG) tests. The findings demonstrated increased cervical JPE and significantly impaired functional balance in CNP patients compared to controls. Notably, JPE values correlated significantly with BBS scores ($r = -0.672$ to -0.732) and TUG scores ($r = 0.328$ to 0.414), indicating a strong link between proprioceptive deficits and balance impairments. These results align with the present study's findings, emphasizing the importance of cervical proprioception in maintaining balance, particularly in populations with cervical and vestibular dysfunction (20).

Despite its strengths, the study had several limitations. The cross-sectional design restricted the ability to establish causality, and the use of purposive sampling limited the generalizability of findings. The age range of participants was also narrow, restricting the applicability of results to younger and older populations. However, the study employed validated tools and provided valuable insights into the relationship between cervical proprioception and balance deficits in individuals with vestibular dysfunction. Future studies with larger, more diverse samples and longitudinal designs are recommended to further elucidate these associations. Additionally, comparisons with healthy individuals could provide a more comprehensive understanding of the role of cervical proprioception in balance regulation. These findings underscore the importance of integrating cervical proprioceptive assessments in the management of vestibular dysfunction to enhance postural control and reduce fall risk.

CONCLUSION

The findings of this study highlight a significant correlation between balance deficits and cervical joint position errors in flexion and extension movements among patients with vestibular dysfunction, while no notable association was observed for rotational movements. This indicates that specific cervical movements play a more critical role in influencing balance outcomes, as measured by the Berg Balance Scale. The results also suggest that overall balance performance may be shaped by additional factors beyond cervical proprioception alone. These insights underscore the complexity of balance regulation in individuals with vestibular dysfunction and emphasize the need for further research to explore targeted strategies for improving balance in this population, particularly by addressing cervical proprioceptive deficits.

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AUTHOR CONTRIBUTIONS

Author	Contribution
Muhammad Zeeshan Anwar*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Uzra Batool	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Muhammad Shahwaiz	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Aqsa Arif	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Hira Rafique	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Hafiz Muddassir Riaz	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

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