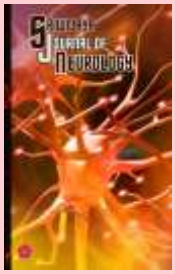

e-ISSN: 2987-1425

Sriwijaya Journal of Neurology (SJN)

Journal website: https://phlox.or.id/index.php/sjn

The Role of the Vestibular System in Balance Disorders and Falls in the Elderly: A Prospective Cohort Study with Posturography Assessment in Surabaya, Indonesia

Venny Melinda[1*], Johan Wirahadi Putro[1], Mariana Alifah[1], Michelle Birne[2], Abhimanyu Putra[3]

[1]Department of Otorhinolaryngology, Phlox Institute, Palembang, Indonesia

[2]Department of Otorhinolaryngology, Darwin State Family Clinic, Darwin, Australia

[3]Department of Otorhinolaryngology, Mutiara Hospital, Southwest Papua, Indonesia

ARTICLE INFO

Keywords:
Balance disorders
Elderly
Falls
Posturography
Vestibular system

***Corresponding author:**
Venny Melinda

E-mail address:
venny.melinda@phlox.or.id

All authors have reviewed and approved the final version of the manuscript.

https://doi.org/10.59345/sjn.v1i2.82

A B S T R A C T

Introduction: Falls in the elderly represent a significant public health concern, often leading to injury, disability, and reduced quality of life. The vestibular system plays a crucial role in maintaining balance, and its decline with age is a major contributor to falls. This study aimed to investigate the relationship between vestibular function, assessed through posturography, and the incidence of falls in elderly individuals in Surabaya, Indonesia. **Methods:** A prospective cohort study was conducted involving 150 participants aged 60 years and above residing in Surabaya. Baseline assessments included a comprehensive geriatric assessment, vestibular function tests using computerized dynamic posturography (CDP), and questionnaires on falls history. Participants were followed up for 12 months to record the occurrence of falls. Data analysis included descriptive statistics, correlation analysis, and logistic regression to identify predictors of falls. **Results:** The incidence of falls during the 12-month follow-up period was 32%. CDP revealed significant age-related decline in vestibular function, particularly in measures of sensory organization and balance strategy. Poor performance on CDP, especially in conditions with altered visual and proprioceptive inputs, was significantly associated with an increased risk of falls. History of previous falls, presence of comorbidities, and use of polypharmacy were also identified as significant predictors of falls. **Conclusion:** Vestibular dysfunction, as assessed by CDP, is a significant risk factor for falls in the elderly. Incorporating posturography assessment into routine geriatric evaluations may help identify individuals at high risk of falls, allowing for targeted interventions to prevent falls and associated complications.

1. Introduction

Falls in the elderly represent a significant public health challenge, with far-reaching consequences for individuals, families, and healthcare systems worldwide. The World Health Organization estimates that 684,000 fatal falls occur each year, with individuals over 60 years of age accounting for the majority of these fatalities. Falls can lead to a range of adverse outcomes, including fractures, head injuries, hospitalization, reduced mobility, loss of independence, and even premature death. In addition to the physical impact, falls can also have significant psychological consequences, such as fear of falling, social isolation, and depression. The prevalence of falls in the elderly varies across different regions and populations, but it is generally recognized as a growing concern due to the aging global population. In high-income countries, the prevalence of falls among community-dwelling older adults is estimated to be around 30%, while in low- and middle-income countries, the prevalence may be even higher due to limited access to healthcare and preventive services.

The economic burden of falls is also substantial, with healthcare costs associated with falls estimated to be in the billions of dollars annually.[1-3]

The etiology of falls in the elderly is complex and multifactorial, involving a dynamic interplay of intrinsic and extrinsic factors. Intrinsic factors refer to individual characteristics that increase the risk of falls, such as age-related physiological changes, underlying medical conditions, medication use, and impaired balance control. Extrinsic factors, on the other hand, relate to environmental hazards that can contribute to falls, such as slippery surfaces, poor lighting, and obstacles in the walking path. Among the intrinsic factors, the decline in vestibular function with age is increasingly recognized as a major contributor to falls. The vestibular system, located in the inner ear, plays a crucial role in maintaining balance and spatial orientation. It provides the brain with sensory information about head position and movement in space, which is integrated with visual and proprioceptive inputs to ensure postural stability. However, age-related changes in the vestibular system can lead to impaired balance control and an increased risk of falls. Age-related changes in the vestibular system include a decrease in hair cells within the vestibular organs, reduced vestibular nerve fibers, and alterations in central vestibular processing. These changes can manifest as dizziness, vertigo, gait disturbances, and an overall decline in balance function. Studies have shown that individuals with vestibular dysfunction are more likely to experience falls compared to those with normal vestibular function.[4-7]

Computerized dynamic posturography (CDP) is a valuable tool for objectively assessing vestibular function and balance control. CDP utilizes a movable platform and visual surround to challenge postural stability under various sensory conditions, providing insights into the individual's ability to integrate sensory information and utilize appropriate balance strategies. Several studies have demonstrated the utility of CDP in identifying elderly individuals at risk of falls. Despite the growing body of evidence supporting the role of vestibular dysfunction in falls among the elderly, research in this area remains limited in Indonesia.[8-10] This study aimed to address this gap by investigating the relationship between vestibular function, assessed through CDP, and the incidence of falls in a prospective cohort of elderly individuals in Surabaya, Indonesia.

2. Methods

The study was conducted at the Geriatric Clinic of a Private Hospital in Surabaya, Indonesia, a major metropolitan city with a diverse population. The study duration was from January 2022 to December 2022, allowing for a 12-month follow-up period to assess the incidence of falls. Ethical approval was obtained from the CMHC Indonesia, ensuring the study adhered to international ethical guidelines for research involving human subjects. All participants provided written informed consent before enrollment, indicating their voluntary participation and understanding of the study procedures. Participants were recruited from the Geriatric Clinic, which provides healthcare services to a large population of older adults in Surabaya. The inclusion criteria were designed to select participants who were representative of the general elderly population, while the exclusion criteria aimed to minimize the influence of confounding factors that could affect balance control and falls risk. A total of 150 participants were included in the study. This sample size was determined based on power calculations to ensure sufficient statistical power to detect meaningful associations between vestibular function and falls.

A comprehensive geriatric assessment was conducted at baseline to gather detailed information about the participants' demographic characteristics, medical history, functional status, and cognitive abilities. This comprehensive approach allowed for a holistic evaluation of the participant's health and potential risk factors for falls. Demographic data collected included age, gender, education level, and living arrangement. These variables were used to describe the characteristics of the study population and to explore potential associations between demographic factors and fall risk. Participants' medical history was assessed to identify chronic diseases and medication use. Chronic diseases, such

as hypertension, diabetes mellitus, and osteoarthritis, are known to increase the risk of falls. Similarly, polypharmacy (the use of multiple medications) is a common problem in the elderly and can contribute to falls due to drug interactions and side effects. Participants were asked about their history of falls in the past year, including the number of falls, circumstances of falls, and any injuries sustained. This information provided valuable insights into the participants' previous falls experience and potential risk factors for future falls. Functional assessment included the Timed Up and Go test and the Berg Balance Scale. The Timed Up and Go test measures the time it takes for a person to stand up from a chair, walk three meters, turn around, walk back to the chair, and sit down. This test assesses mobility and balance confidence. The Berg Balance Scale is a 14-item scale that assesses static and dynamic balance abilities. Cognitive function was assessed using the Mini-Mental State Examination (MMSE). The MMSE is a widely used screening tool for cognitive impairment. Participants with MMSE scores below 24 were excluded from the study to ensure that cognitive impairment did not confound the assessment of vestibular function and falls risk.

CDP is a sophisticated method for evaluating balance control under various sensory conditions. The NeuroCom Equitest system, used in this study, is a commercially available CDP system that has been extensively validated for research and clinical use. The SOT is a core component of CDP that assesses the individual's ability to maintain balance under six different sensory conditions. These conditions systematically manipulate visual, vestibular, and proprioceptive inputs to challenge postural stability and identify potential sensory deficits contributing to balance impairment. The SOT provides an Equilibrium Score for each condition, ranging from 0 to 100, with higher scores indicating better balance control. The Equilibrium Score is a composite measure that reflects the individual's ability to integrate sensory information and maintain postural stability. In addition to the Equilibrium Score, the SOT also generates a sensory analysis, which provides detailed information about the individual's reliance on different sensory inputs for balance control. This analysis can help identify specific sensory deficits that may be contributing to balance impairment.

Participants were followed up for 12 months through telephone interviews conducted every three months. This regular follow-up allowed for the timely identification and recording of falls, minimizing recall bias and ensuring the accuracy of falls data. During the telephone interviews, participants were asked about the occurrence of falls, including the number of falls, circumstances surrounding the falls, and any injuries sustained. This detailed information allowed for a comprehensive analysis of falls and their potential consequences.

Data analysis was performed using SPSS version 26, a comprehensive statistical software package widely used in healthcare research. Descriptive statistics were used to summarize participant characteristics and baseline data. This included measures of central tendency (e.g., mean, median) and dispersion (e.g., standard deviation, range) to describe the distribution of data. Correlation analysis was used to examine the relationship between age, vestibular function measures (SOT scores), and other variables. This allowed for the identification of potential associations between these variables and falls risk. Logistic regression analysis was performed to identify independent predictors of falls during the 12-month follow-up period. This multivariate analysis allowed for the control of confounding factors and the identification of specific variables that were independently associated with falls risk. A p-value of <0.05 was considered statistically significant, indicating that the observed associations were unlikely to be due to chance alone.

3. Results

Table 1 provides a detailed overview of the characteristics of the 150 participants enrolled in the study. The average age of participants was 72.5 years, indicating that the study sample included individuals across the spectrum of older adulthood. The majority of participants fell within the 70-79 year age range (40%), followed by 60-69 years (36.7%) and 80+ years (23.3%). This distribution reflects the typical age range

of individuals seen in geriatric clinics and allows for the examination of age-related changes in vestibular function and falls risk. A greater proportion of participants were female (62%) compared to male (38%). This is consistent with the general demographics of older populations, where women tend to have a longer life expectancy than men. Over half of the participants (53.3%) had only a primary school education, with 25.3% having secondary school education and a small percentage (6.7%) having tertiary education. This suggests that the study sample included individuals with diverse educational backgrounds, which may be relevant to understanding health literacy and adherence to fall prevention strategies. The majority of participants lived with family (60%), followed by living with a spouse (30%). Only 10% of participants lived alone. This highlights the importance of family support in the care of older adults and the potential impact of living arrangements on falls risk. The prevalence of chronic diseases was high in this population, with hypertension being the most common (64%), followed by diabetes mellitus (32%) and osteoarthritis (28%). These conditions are known risk factors for falls and may contribute to balance impairments and functional limitations. A significant proportion of participants (40%) were taking five or more medications, indicating a high prevalence of polypharmacy. Polypharmacy is a concern in the elderly as it can increase the risk of adverse drug events and falls. 28% of participants reported a history of falls in the past year. This finding underscores the prevalence of falls in this population and the need for effective fall prevention strategies.

Table 1. Participant characteristics.

Characteristic	Number (n=150)	Percentage (%)
Age (years)		
Mean ± SD	72.5	
60-69	55	36.7
70-79	60	40.0
80+	35	23.3
Gender		
Female	93	62.0
Male	57	38.0
Education level		
No formal education	22	14.7
Primary school	80	53.3
Secondary school	38	25.3
Tertiary education	10	6.7
Living arrangement		
Alone	15	10.0
With spouse	45	30.0
With family	90	60.0
Chronic diseases		
Hypertension	96	64.0
Diabetes mellitus	48	32.0
Osteoarthritis	42	28.0
Cardiovascular disease (excluding hypertension)	30	20.0
Chronic respiratory disease	24	16.0
Polypharmacy (≥5 medications)	60	40.0
History of falls (past year)	42	28.0

Table 2 provides a detailed account of the falls experienced by the 42 participants who reported falling in the year prior to the study. This information offers valuable insights into the circumstances surrounding falls in this population; Number of Falls in the Past Year: Most participants (59.5%) had experienced a single fall in the past year. A smaller proportion (28.6%) reported two falls, and a minority (11.9%) experienced three or more falls. This suggests that while single falls are common, a subset of individuals may be at higher risk for recurrent falls, potentially due to underlying balance impairments or environmental hazards; Circumstances of Falls: Tripping was the most common circumstance leading to a fall (45.2%), highlighting the importance of environmental factors like uneven surfaces or obstacles. Slipping was the second most frequent cause (26.2%), indicating that slippery surfaces, particularly in bathrooms and kitchens, pose a significant risk. Loss of balance while walking (19%) and standing (4.8%) suggest underlying issues with balance control and postural stability, potentially related to age-related decline in vestibular function or other factors. Dizziness/vertigo was reported in a small percentage of falls (4.8%), indicating that vestibular disorders may contribute to falls in some individuals; Location of Falls: The majority of falls occurred at home (64.3%), emphasizing the need for home safety assessments and modifications to prevent falls in this environment. Outdoor falls accounted for 26.2% of incidents, suggesting that uneven terrain, obstacles, and weather conditions may contribute to falls outside the home. Falls in public places were relatively less common (9.5%); Injuries Sustained: Most falls (66.7%) did not result in any injuries, which is reassuring. However, 23.8% of falls led to soft tissue injuries like bruises or sprains, and a small percentage (9.5%) resulted in fractures. This highlights the potential for falls to cause significant injuries, even in the absence of major trauma.

Table 2. Baseline falls history.

Characteristic	Number (n=42)	Percentage (%)
Number of falls in the past year		
1	25	59.5
2	12	28.6
3+	5	11.9
Circumstances of falls		
Tripping	19	45.2
Slipping	11	26.2
Loss of balance while walking	8	19.0
Loss of balance while standing	2	4.8
Dizziness/Vertigo	2	4.8
Location of falls		
Home	27	64.3
Outdoors	11	26.2
Public places	4	9.5
Injuries sustained		
None	28	66.7
Soft tissue injury (bruises, sprains)	10	23.8
Fracture	4	9.5

Table 3 presents the mean equilibrium scores for each of the six Sensory Organization Test (SOT) conditions, broken down by age group. This allows us to see how well participants in different age ranges maintain their balance when faced with varying sensory challenges. Across all six SOT conditions, there's a clear trend of decreasing equilibrium scores with increasing age. This indicates that older

participants, particularly those aged 80 and above, demonstrate reduced postural stability compared to their younger counterparts. This aligns with the expected age-related decline in vestibular function and sensory integration; Condition 1 (Fixed platform, eyes open, visual surround fixed): This is the easiest condition, relying on all sensory systems. Even here, we see a gradual decline in scores with age, though it's less pronounced than in other conditions; Condition 2 (Fixed platform, eyes closed, visual surround fixed): Removing visual input makes the task harder, and the age-related decline becomes more apparent. This suggests that older adults rely more on vision for balance and have greater difficulty compensating when it's taken away; Condition 3 (Fixed platform, eyes open, visual surround sway-referenced): This condition introduces conflicting visual information. The decline in scores with age is significant, indicating that older adults struggle more with integrating accurate visual input when it conflicts with other sensory cues; Condition 4 (Sway-referenced platform, eyes open, visual surround fixed): Here, the support surface moves, challenging proprioceptive input. Again, we see a clear decline with age, suggesting reduced ability to utilize proprioceptive information for balance; Condition 5 (Sway-referenced platform, eyes closed, visual surround fixed): This is one of the most challenging conditions, with both visual and proprioceptive inputs compromised. Older adults show the most significant decline in this condition, highlighting their increased reliance on visual and proprioceptive cues for balance; Condition 6 (Sway-referenced platform, eyes open, visual surround sway-referenced): This is the hardest condition, with conflicting visual and proprioceptive information. The age-related decline is substantial, indicating that older adults have the greatest difficulty integrating sensory information and maintaining balance in complex, challenging situations.

Table 3. Mean equilibrium scores for SOT conditions by age group.

Age Group (Years)	Condition 1	Condition 2	Condition 3	Condition 4	Condition 5	Condition 6
60-69	85.2 ± 8.5	78.5 ± 9.2	72.3 ± 10.1	76.8 ± 9.8	69.5 ± 10.5	65.4 ± 11.2
70-79	82.1 ± 9.1	74.3 ± 10.0	68.1 ± 11.3	73.5 ± 10.6	65.8 ± 11.8	61.2 ± 12.5
80+	78.5 ± 10.3	69.8 ± 11.5	63.7 ± 12.8	69.2 ± 12.1	61.5 ± 13.2	56.8 ± 14.1

Table 4 provides a comprehensive picture of the falls that occurred among the participants during the 12-month follow-up period. This data is crucial for understanding the characteristics and consequences of falls in this elderly population; Number of Falls: Similar to the baseline falls history, a majority of participants (64.6%) experienced a single fall during follow-up. 25% had two falls, and a smaller proportion (10.4%) had three or more falls. This suggests a pattern of recurrent falls in some individuals, highlighting the need for ongoing fall prevention efforts; Circumstances of Falls: Tripping remained the most common circumstance (43.8%), reinforcing the importance of addressing environmental hazards. Slipping was the second most frequent cause (27.1%), again emphasizing the need for safe flooring and footwear. Loss of balance while walking (18.8%) was also notable, suggesting that gait and balance impairments play a significant role in falls. Loss of balance while standing (6.3%) and dizziness/vertigo (4.2%) were less frequent but still indicate the contribution of balance disorders and potential vestibular dysfunction; Location of Falls: Consistent with baseline data, most falls occurred at home (64.6%), underscoring the need for home safety interventions. Falls outdoors (25%) and in public places (10.4%) were also observed, highlighting the importance of fall prevention strategies in various environments; Activity at Time of Fall: Walking was the most common activity associated with falls (54.2%), emphasizing the need for gait training and balance exercises. Transferring (e.g., sit-to-stand) accounted for 16.7% of falls, highlighting the challenges faced during transitions between positions.

Reaching/bending (14.6%) and other activities (14.6%) also contributed to falls, suggesting that everyday tasks can pose a risk for older adults; Injuries Sustained: Most falls (68.8%) did not result in injuries. However, 20.8% led to soft tissue injuries, and 10.4% resulted in fractures. This emphasizes the potential for significant injuries and the need for interventions to minimize fall-related harm; Medical Attention Sought: Over half of the participants (58.3%) did not seek medical attention after a fall. This may indicate underreporting of falls or a reluctance to seek help. 31.3% consulted a general practitioner, and 10.4% required hospitalization. This highlights the burden of falls on healthcare services and the need for timely medical assessment after a fall.

Table 4. Falls during follow-up.

Characteristic	Number (n=48)	Percentage (%)
Number of falls		
1	31	64.6
2	12	25.0
3+	5	10.4
Circumstances of falls		
Tripping	21	43.8
Slipping	13	27.1
Loss of balance while walking	9	18.8
Loss of balance while standing	3	6.3
Dizziness/Vertigo	2	4.2
Location of falls		
Home	31	64.6
Outdoors	12	25.0
Public places	5	10.4
Activity at the time of fall		
Walking	26	54.2
Transferring (e.g., sit-to-stand)	8	16.7
Reaching/Bending	7	14.6
Other	7	14.6
Injuries sustained		
None	33	68.8
Soft tissue injury (bruises, sprains)	10	20.8
Fracture	5	10.4
Medical attention sought		
None	28	58.3
General practitioner	15	31.3
Hospitalization	5	10.4

Table 5 presents the results of a logistic regression analysis, which was used to identify independent predictors of falls in the study participants. This analysis helps us understand which factors are most strongly associated with an increased risk of falling, even after accounting for other variables; History of previous falls: Having a history of falls was the strongest predictor, with an odds ratio (OR) of 4.82. This means that individuals with a history of falls were nearly five times more likely to fall again during the follow-up period compared to those without a history of falls. This highlights the importance of early identification and intervention for individuals who have experienced a fall; SOT Condition 3 (visual conflict), Equilibrium Score < 70: Participants with an equilibrium score below 70 in SOT Condition 3 (where

visual information conflicts with other sensory cues) had an OR of 3.15, indicating a more than threefold increased risk of falls. This suggests that difficulty integrating conflicting visual input is a significant risk factor; SOT Condition 5 (proprioceptive conflict), Equilibrium Score < 65: Similarly, participants with an equilibrium score below 65 in SOT Condition 5 (where proprioceptive information is unreliable) had an OR of 2.87, indicating a nearly threefold increased risk of falls. This highlights the importance of proprioceptive input for balance control and fall prevention; Polypharmacy (≥5 medications): Taking five or more medications was associated with an OR of 2.31, indicating a more than twofold increased risk of falls. This underscores the potential negative impact of polypharmacy on balance and mobility in older adults; Number of Comorbidities: Each additional comorbidity (chronic disease) was associated with an OR of 1.25, indicating a 25% increased risk of falls. This emphasizes the cumulative effect of chronic diseases on fall risk; Age (per 1-year increase): Each year increase in age was associated with an OR of 1.08, indicating an 8% increased risk of falls. This confirms the well-established link between aging and fall risk; Gender (Female): Although females had a slightly higher odds of falling (OR 1.50), this was not statistically significant; Living Arrangement (Alone): Living alone was also not a significant predictor of falls in this analysis.

Table 5. Logistic regression analysis of predictors of falls.

Predictor	Odds Ratio (OR)	95% Confidence Interval (CI)	p-value
History of previous falls	4.82	2.15 - 10.81	<0.001
SOT Condition 3 (visual conflict), Equilibrium Score < 70	3.15	1.52 - 6.53	0.002
SOT Condition 5 (proprioceptive conflict), Equilibrium Score < 65	2.87	1.38 - 5.97	0.005
Polypharmacy (≥5 medications)	2.31	1.08 - 4.94	0.031
Number of Comorbidities	1.25	1.05 - 1.49	0.012
Age (per 1-year increase)	01.08	1.01 - 1.15	0.025
Gender (Female)	1.50	0.72 - 3.13	0.281
Living Arrangement (Alone)	1.75	0.65 - 4.70	0.265

4. Discussion

This study unearthed a series of critical findings that shed light on the complex issue of falls in the elderly population of Surabaya, Indonesia. The study revealed a striking 32% incidence of falls among participants during the 12-month follow-up period. This figure paints a stark picture of the prevalence of falls within this demographic, underscoring the urgency for effective fall prevention strategies. It signifies that almost one-third of the elderly individuals participating in this study experienced at least one fall within a year. This high incidence rate aligns with global trends, as previous studies conducted in various countries have reported fall rates ranging from 10% to 30% in community-dwelling older adults. However, it's crucial to recognize that this figure may only represent the tip of the iceberg. Underreporting of falls is a common phenomenon, particularly among older adults who may fear losing their independence or being perceived as frail. Therefore, the actual incidence of falls in the community could be even higher than what was observed in this study. The implications of this high incidence rate are far-reaching. Fractures, particularly

hip fractures, are a common consequence of falls in older adults. These injuries can lead to prolonged hospitalization, disability, and reduced quality of life. Falls can also have a profound psychological impact, leading to fear of falling, loss of confidence, and social isolation. This fear can further restrict activity levels, contributing to a decline in physical function and overall well-being. Falls place a significant burden on healthcare systems due to the costs associated with hospitalization, rehabilitation, and long-term care. The study's CDP assessments provided compelling evidence of a significant age-related decline in vestibular function. This decline was particularly evident in measures of sensory organization and balance strategy, which are crucial for maintaining postural stability in challenging environments. The vestibular system, located in the inner ear, plays a pivotal role in balance control. It works in concert with the visual and proprioceptive systems to provide the brain with information about the body's position and movement in space. However, the vestibular system undergoes age-related changes that can compromise its effectiveness. Hair cells within the vestibular organs, which detect head movement, decrease in number with age. This can lead to reduced sensitivity to head motion and impaired balance. The number of nerve fibers transmitting vestibular information to the brain also declines with age. This can slow down the processing of vestibular signals and impair the ability to react quickly to maintain balance. The brain regions responsible for processing vestibular information may also undergo age-related changes, affecting the integration of sensory input and the execution of appropriate motor responses. The observed decline in vestibular function has direct implications for fall risk. Dizziness and vertigo sensations can disrupt balance and increase the likelihood of falls. Changes in gait patterns, such as reduced step length and increased variability, can occur due to impaired vestibular function, making walking less stable and increasing fall risk. Older adults with vestibular decline may struggle to integrate conflicting sensory information, particularly in situations where visual or proprioceptive cues are unreliable. This can lead to instability and falls in challenging environments. The logistic regression analysis highlighted the multifactorial nature of falls, identifying several independent predictors beyond vestibular dysfunction. Individuals with a history of falls are at a significantly higher risk of falling again. This may be due to a combination of factors, including underlying balance impairments, fear of falling, and reduced activity levels. Difficulty with sensory integration, particularly in conditions involving visual and proprioceptive conflicts, was a strong predictor of falls. This underscores the importance of assessing and addressing sensory integration deficits in fall prevention programs. The use of multiple medications, a common occurrence in older adults, can increase fall risk due to drug interactions and side effects. Medications that affect the central nervous system, such as sedatives and antidepressants, can impair balance and coordination. The presence of multiple chronic diseases can contribute to fall risk by affecting various systems involved in balance control, such as the cardiovascular, musculoskeletal, and neurological systems. Age remains a significant risk factor for falls, as it is associated with a decline in various physiological functions that contribute to balance and mobility. These findings emphasize the complex interplay of intrinsic and extrinsic factors that contribute to fall risk. Effective fall prevention strategies must address not only individual risk factors but also environmental hazards and modifiable lifestyle factors.[11-13]

This study delves into the intricate relationship between vestibular function and falls in the elderly, providing compelling evidence that underscores the critical role of the vestibular system in maintaining balance and preventing falls. The findings unequivocally demonstrate that impaired vestibular function is a significant risk factor for falls in older adults. Participants who exhibited lower equilibrium scores on specific SOT conditions, particularly those involving visual and proprioceptive conflicts, were substantially more likely to experience falls during the follow-up period. This observation points to a crucial aspect of vestibular function, the ability to integrate sensory information from various sources and adapt to challenging sensory environments. The vestibular

system, often referred to as our "sixth sense," is a complex sensory system located in the inner ear. It works tirelessly in the background, providing the brain with crucial information about head position and movement in space. This information is seamlessly integrated with input from the visual and proprioceptive systems (which sense body position and movement) to ensure postural stability and coordinated movement. However, the vestibular system, like other physiological systems, is susceptible to age-related changes that can compromise its effectiveness. Peripheral vestibular dysfunction involves changes in the inner ear structures responsible for detecting head movement. Loss of hair cells, which are the sensory receptors within the vestibular organs, can lead to reduced sensitivity to head motion. Degeneration of the vestibular nerve, which transmits signals from the inner ear to the brain, can also impair the transmission of vestibular information. Central vestibular dysfunction involves changes in the brain regions responsible for processing and integrating vestibular information. Age-related alterations in these brain areas can affect the ability to interpret vestibular signals accurately and generate appropriate motor responses to maintain balance. Dizziness and vertigo often described as a spinning or swaying feeling, can be particularly disorienting and increase the risk of falls. Impaired vestibular function can affect gait patterns, leading to reduced step length, increased step width, and greater variability in walking. These gait disturbances can compromise stability and increase the likelihood of falls. Difficulty maintaining an upright posture, especially when challenged by external perturbations or changes in sensory input, is a common manifestation of vestibular dysfunction. This instability can make individuals more susceptible to falls. The study's focus on SOT conditions involving visual and proprioceptive conflicts highlights the importance of sensory integration in maintaining balance. In everyday life, we constantly encounter situations where sensory information from different sources may be conflicting or unreliable. For example, walking on a moving walkway or navigating a crowded street requires the ability to integrate visual, vestibular, and proprioceptive cues to maintain stability. Older adults with vestibular dysfunction may struggle to process and integrate these conflicting sensory cues effectively. This can lead to instability and an increased risk of falls, particularly in challenging environments. Furthermore, the ability to adapt to changes in sensory environments is crucial for maintaining balance. For example, when transitioning from a well-lit room to a dimly lit hallway, the visual system becomes less reliable, and the brain must rely more on vestibular and proprioceptive input to maintain stability. Older adults with vestibular impairments may have difficulty adapting to these changes in sensory input, increasing their vulnerability to falls. The findings of this study are not in isolation. They add to a growing body of evidence that supports the link between vestibular dysfunction and falls in older adults. Numerous studies, employing various methods to assess vestibular function, have consistently demonstrated that individuals with vestibular impairments are more likely to experience falls compared to those with normal vestibular function. Clinical tests include bedside tests such as the head impulse test, the Dix-Hallpike maneuver, and the Romberg test, which can provide preliminary indications of vestibular dysfunction. Laboratory tests include electronystagmography (ENG) and videonystagmography (VNG), which measure eye movements to assess vestibular function. Computerized Dynamic Posturography (CDP), this sophisticated technology, used in the current study, provides a comprehensive assessment of balance control under various sensory conditions, allowing for the identification of specific vestibular deficits. The strong association between vestibular dysfunction and falls has important implications for clinical practice. Healthcare providers should be vigilant about identifying older adults with potential vestibular impairments. Incorporating vestibular screening into routine geriatric assessments can facilitate early detection and intervention. VRT is an effective intervention for improving balance function in individuals with vestibular impairments. It involves a series of exercises and activities designed to improve gaze stability, postural control, and gait. VRT can help

individuals adapt to sensory conflicts, improve their balance, confidence, and reduce their risk of falls. Addressing vestibular dysfunction often requires a multidisciplinary approach involving physicians, physical therapists, and other healthcare professionals. This collaborative approach can ensure that individuals receive comprehensive care tailored to their specific needs.[14-17]

While vestibular dysfunction emerged as a key player in falls among the elderly, this study also unveiled a constellation of other significant predictors. These findings underscore the multifactorial nature of falls, painting a complex picture that necessitates a comprehensive approach to prevention and management. The study unequivocally identified a history of previous falls as a potent predictor of future falls. Individuals who had experienced a fall in the past were substantially more likely to fall again during the follow-up period. This finding aligns with a wealth of research that consistently points to a history of falls as a robust risk factor. A previous fall may signal underlying balance deficits that persist and continue to pose a risk. These deficits could stem from various sources, including vestibular dysfunction, musculoskeletal limitations, or neurological conditions. The experience of a fall can trigger a fear of falling, leading to a vicious cycle. This fear can lead to reduced activity levels, decreased confidence in one's balance abilities, and ultimately, an increased risk of further falls. Following a fall, individuals may subconsciously or consciously alter their gait patterns and movement strategies in an attempt to avoid another fall. However, these adaptations may sometimes be counterproductive, leading to less stable movement and an increased risk of falls. Polypharmacy, the concurrent use of multiple medications, is a prevalent issue among older adults, often arising from the management of multiple chronic conditions. This study identified polypharmacy as an independent predictor of falls, highlighting the potential adverse effects of medications on balance and mobility. When multiple medications are taken simultaneously, interactions between drugs can occur, leading to unexpected side effects that may impair balance or coordination. Many medications, particularly those that affect the central nervous system, can have side effects that increase fall risk. Sedatives, antidepressants, and antihypertensives, for example, can cause drowsiness, dizziness, or orthostatic hypotension (a sudden drop in blood pressure upon standing), all of which can compromise balance and increase the likelihood of falls. Age-related changes in the body's ability to absorb, metabolize, and eliminate drugs can lead to altered drug levels in the bloodstream. This can increase the risk of side effects and adverse events, including falls. The presence of multiple chronic diseases, or comorbidities, also emerged as a significant predictor of falls in this study. This finding underscores the interconnectedness of various health conditions and their cumulative impact on fall risk. Certain chronic conditions, such as Parkinson's disease, stroke, and peripheral neuropathy, can directly affect the neurological and musculoskeletal systems involved in balance control. Other chronic conditions, such as heart disease, lung disease, and arthritis, may not directly affect balance systems but can indirectly increase fall risk by impairing overall functional status, reducing mobility, and causing fatigue. The management of multiple chronic conditions often necessitates the use of multiple medications, increasing the risk of polypharmacy and its associated adverse effects on balance. Age, while a non-modifiable risk factor, remains a significant predictor of falls. The aging process is associated with a gradual decline in various physiological functions that contribute to balance and mobility. As discussed earlier, the vestibular system undergoes age-related changes that can impair its ability to detect head movement and maintain balance. Muscle mass and strength tend to decline with age, particularly in the lower extremities. This can affect gait stability and increase the risk of falls. The ability to react quickly to perturbations or changes in the environment declines with age. This can make it more difficult to recover from a stumble or regain balance, increasing the likelihood of a fall. Age-related changes in joints can lead to decreased flexibility and range of motion, which can affect gait patterns and balance. A thorough assessment of older adults should include a comprehensive evaluation of

medical history, medication use, functional status, and balance abilities. This can help identify individuals at high risk of falls and guide the development of targeted interventions. Regular medication reviews are essential to identify potentially inappropriate medications and minimize the risk of polypharmacy. Deprescribing or adjusting dosages of medications that affect the central nervous system may be necessary to reduce fall risk. Optimal management of chronic diseases is crucial for minimizing their impact on balance and mobility. This includes regular monitoring, appropriate treatment, and lifestyle modifications to improve overall health and functional status. Exercise programs that focus on strengthening muscles, improving balance, and increasing flexibility can help mitigate the age-related decline in physical function and reduce fall risk. Home safety assessments and modifications can help eliminate environmental hazards that contribute to falls. This may include removing tripping hazards, installing grab bars in bathrooms, and improving lighting.[18-20]

5. Conclusion

Our findings indicate that incorporating posturography assessment into routine geriatric evaluations could significantly improve fall risk identification and facilitate targeted interventions. The study underscores the multifactorial nature of falls in the elderly, with a history of previous falls, sensory integration difficulties, polypharmacy, and the presence of comorbidities emerging as significant independent predictors of falls. These findings, however, are subject to certain limitations, including the study's confinement to a single geriatric clinic in Surabaya, Indonesia, potentially restricting its generalizability to other populations. The study's reliance on self-reported falls, though mitigated by regular follow-up calls, introduces the possibility of recall bias. Despite these limitations, the study's results contribute significantly to our understanding of fall risk factors in the elderly, particularly within the Indonesian context. Future research should focus on expanding the study population to include participants from diverse socioeconomic backgrounds and geographical locations within Indonesia. This would provide a more comprehensive understanding of the interplay between vestibular function, falls, and various risk factors across different segments of the elderly population. By addressing these critical areas, we can further enhance our knowledge of fall prevention strategies and contribute to improving the quality of life for the elderly.

6. References

1. Xing L, Bao Y, Wang B, Shi M, Wei Y, Huang X, et al. Falls caused by balance disorders in the elderly with multiple systems involved: Pathogenic mechanisms and treatment strategies. Front Neurol. 2023; 14: 1128092.
2. Manrique MJ, Batuecas Á, Cenjor C, Ferrán S, Gómez JR, Lorenzo AI, et al. Presbycusis and balance disorders in the elderly. Bibliographical review of ethiopathogenic aspects, consequences on quality of life and positive effects of its treatment. Acta Otorrinolaringol (Engl Ed). 2023; 74(2): 124–32.
3. Xu F, Soh KG, Chan YM, Bai XR, Qi F, Deng N. Effects of tai chi on postural balance and quality of life among the elderly with gait disorders: a systematic review. PLoS One. 2023; 18(9): e0287035.
4. Swanenburg J, de Bruin ED, Favero K, Uebelhart D, Mulder T. The reliability of postural balance measures in single and dual tasking in elderly fallers and non-fallers. BMC Musculoskelet Disord. 2008; 9(1): 162.
5. Drzał-Grabiec J, Rachwał M, Podgórska-Bednarz J, Rykała J, Snela S, Truszczyńska A, et al. The effect of spinal curvature on the photogrammetric assessment on static balance in elderly women. BMC Musculoskelet Disord. 2014; 15(1): 186.
6. Monteiro-Junior RS, Ferreira AS, Puell VN, Lattari E, Machado S, Otero Vaghetti CA, et al. Wii Balance Board: Reliability and clinical use in assessment of balance in healthy elderly women. CNS Neurol Disord Drug Targets. 2015; 14(9): 1165–70.

7. Méndez-Rial B, Cancela JM, Ayan C, Vila MH. Alterations in the dynamic balance level in elderly with Parkinson's disease. Parkinsonism Relat Disord. 2016; 22: e52.
8. Fiore V, Barucca A, Barraco S, Triggiani D, Tragni D, Piazzolla G, et al. Dyslipidemia and cardiovascular prevention in the elderly: a balance between benefits and risks of statin treatment in a specific population. Endocr Metab Immune Disord Drug Targets. 2023; 23(11): 1371–9.
9. Cai Z, She J, Guo S, Li R, Zhang H, Guo X, et al. Association between oxidative balance score and abdominal aortic calcification among middle-aged and elderly population. BMC Cardiovasc Disord. 2022; 24(1): 539.
10. Terroso M, Rosa N, Torres Marques A, Simoes R. Physical consequences of falls in the elderly: a literature review from 1995 to 2010. Eur Rev Aging Phys Act. 2014; 11(1): 51–9.
11. Pyrgeli M, Agapiou E, Pyrgelis E-S, Manaras D, Dionyssiotis Y, Dontas I. The correlation of specific medication groups and falls risk in elderly. A medication logbook survey. J Frailty Sarcopenia Falls. 2017; 2(4): 92–8.
12. McCrum C, Gerards MHG, Karamanidis K, Zijlstra W, Meijer K. A systematic review of gait perturbation paradigms for improving reactive stepping responses and falls risk among healthy older adults. Eur Rev Aging Phys Act. 2017; 14(1): 3.
13. Kim D, Ahrentzen S. Environmental and behavioral circumstances and consequences of falls in a senior living development. J Hous Elderly. 2017; 31(3): 286–301.
14. Neves T, Ferriolli E, Lopes MBM, Souza MGC, Fett CA, Fett WCR. Prevalence and factors associated with sarcopenia and dynapenia in elderly people. J Frailty Sarcopenia Falls. 2018; 3(4): 194–202.
15. Krumov J, Obretenov V, Vodenicharova A, Kanalev K, Stavrev V, Troev T, et al. The benefits to functional ambulation and physical activity of group-based rehabilitation in frail elderly Bulgarians undergoing total knee arthroplasty. Preliminary results. J Frailty Sarcopenia Falls. 2019; 4(1): 20–5.
16. Mulligan A, Seman M, Abramowski R, Falls R, Scholes E, Vogrin S, et al. Cardio-geriatric model of care in acute heart failure: initial experience of a multidisciplinary approach in complex elderly patients. Intern Med J. 2020; 50(4): 488–92.
17. Terzis N, Salonikidis K, Apostolara P, Roussos N, Karzis K, Ververidis A, et al. Can the exercise-based and occupational therapy improve the posture, strength, and mobility in elderly Greek subjects with hip fracture? A non-randomized control trial. J Frailty Sarcopenia Falls. 2021; 6(2): 57–65.
18. Niederer D, Engeroff T, Fleckenstein J, Vogel O, Vogt L. The age-related decline in spatiotemporal gait characteristics is moderated by concerns of falling, history of falls & diseases, and sociodemographic-anthropometric characteristics in 60-94 years old adults. Eur Rev Aging Phys Act. 2021; 18(1): 19.
19. Wiedenmann T, Held S, Rappelt L, Grauduszus M, Spickermann S, Donath L. Exercise based reduction of falls in communitydwelling older adults: a network meta-analysis. Eur Rev Aging Phys Act. 2023; 20(1): 1.
20. Jacobson GP, McCaslin DL, Grantham SL, Piker EG. Significant vestibular system impairment is common in a cohort of elderly patients referred for assessment of falls risk. J Am Acad Audiol. 2008; 19(10): 799–807.