NEWSLETTER-TOPICS IN VESTIBULAR PHYSICAL THERAPY JAN 2025 WINTER EDITION

TOPICS IN VESTIBULAR PHYSICAL THERAPY

VESTIBULAR REHABILITATION SIG

APTA & Academy of Neurologic Physical Therapy

NEURODEGENERATIVE DISEASES & VESTIBULAR DYSFUNCTION

IN THIS ISSUE PAGE

CLINICAL CASE STUDIES

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Message from the Chair

Rachel Wellons, PT, DPT*
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When you look at the neuroanatomical distribution and connections of the central vestibular system, it's awe-inspiring that this one system traverses and connects such diverse parts of the brain. For a long time, patients with central vestibular disorders were underrecognized because many of them may not experience typical vertiginous dizziness episodes. Those disorders which are degenerative in nature may be even more underrecognized because they often progress slowly and those impacted may not realize the impact. I'm very excited to learn more about the role of Vestibular Rehabilitation in those with degenerative disorders in this issue.

The Vestibular Rehabilitation Special Interest Group (SIG) prides itself on being an organization that supports Vestibular Physical Therapists through education and collaboration; however, we also have an important role in advocacy. Thanks to **Kathleen Stross** who serves as our Vestibular Disorders Association (VeDA) Liaison. Kathleen worked with volunteers **Jadean Hoff**, **Stephanie Mahan**, **Victoria Gaugis**, **Will Bernaldo**, **Nidhi Seth**, **Jenni Keltgen**, **Kristy List**, **Hilary Register**, and **Celeste Delap**. These individuals investigated how our two organizations can collaborate and pool resources to best support Vestibular Therapists and advocate for individuals with vestibular disorders. We look forward to putting their ideas into action over the next year. We are thankful to VeDA for offering all new Vestibular Rehabilitation SIG members a complimentary membership for a year. We encourage all of our members to support VeDA as well.

Another effort that we have been working hard on behind the scenes has been the Vestibular Fact Sheets. Many of the fact sheets were created long ago, and of course, new research has changed knowledge and practice. Dawn Fitzgerald and Heidi Roth co-chair the committee to evaluate all our existing fact sheets and to create a plan to update them. Thanks to our volunteers who updated the fact sheets that they originally authored or assisted with updating fact sheets: **Tara Andrews**, **Matthew Bjelac**, **Jennifer Braswell Christy**, **Lisa Farrell**, **April Hodges**, **Lisa Heusel-Gillig**, **Sara MacDowell**, **Suzanne Moore**, **Laura Morris**, **Lexi Miles**, **Allison Nogi**, **Heidi Roth**, **Britta Smith**, **Stephen Vandenberg**, **Sue Whitney**, and **Geoff Willard**.

I look forward to seeing all of you at CSM. As per usual, there's a great slate of Vestibular programming. I look forward to seeing everyone at the Vestibular Rehabilitation SIG table at the Myelin Melter on Friday, February 14th at 6:30 pm. Vestibular Rehabilitation SIG Service and Research awards will be awarded then.

We are an organization only as strong as our leadership team and members! I am thankful for the tremendous Vestibular Rehabilitation SIG leadership team that volunteers their time to support our initiatives.

Introduction to the Topic

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Central Vestibular Dysfunction in Persons with Neurodegenerative Diseases

The central vestibular system includes several interconnected structures in the brainstem, cerebellum, sub-cortical areas, and cortical regions. These areas collectively regulate vestibular reflexes and support balance, gait, gaze stabilization, spatial orientation, navigation, and more. Damage to areas involved in vestibular processing can result in significant functional deficits. Indeed, vestibular impairments are common in persons with neurological disorders, and vestibular rehabilitation is becoming more widely recognized as an essential component of physical therapy for affected individuals. Understanding how lesions in the central vestibular system manifest in persons with neurodegenerative conditions is crucial for developing effective interventions. However, robust evidence for the effectiveness of vestibular rehabilitation in persons with neurodegenerative conditions is sparse, (1) and there are no clinical practice guidelines to inform our clinical decision-making as vestibular physical therapists.

In the previous edition of Topics in Vestibular Physic al Therapy, our contributors demonstrated the role of vestibular rehabilitation in persons with pontine, cerebellar, and middle cerebral artery stroke. Herein, we examine the effects of central vestibular system damage in persons with neurodegenerative conditions and we provide examples of effective vestibular rehabilitation interventions for three patients. First, Lewis and Klatt make evidence-informed recommendations for vestibular interventions for persons with cognitive impairments and Alzheimer's disease (AD). Additionally, Morris and Grove discuss the evidence for vestibular dysfunction and the role of vestibular therapy in persons with multiple sclerosis (MS). Finally, Millar describes a comprehensive approach to rehabilitation for persons with cerebellar degeneration, specifically cerebellar ataxia, neuropathy, and vestibular areflexia syndrome (CANVAS).

To provide a firm foundation for the case studies that follow, this article provides a review of the major vestibular outputs and the evidence of vestibular dysfunction in persons with neurodegenerative conditions. Specifically, evidence for abnormal vestibular function tests in persons with Parkinson's disease (PD), multiple system atrophy (MSA), progressive supranuclear palsy (PSP), MS, CANVAS, and AD is examined.

The Central Vestibular System in Health and Neurodegenerative Diseases

Although the vestibular system plays roles in balance, gait, gaze stabilization, spatial orientation, navigation, cognition, and autonomic regulation, our focus is on the vestibular system's three primary outputs that serve distinct but interconnected functions. These efferent systems are the vestibulo-ocular reflex (VOR), which ensures gaze stability; the vestibulospinal reflex (VSR), which maintains postural stability; and the vestibulocortical system, which supports spatial orientation and navigation.

Vestibulo-Ocular Reflex (VOR)

The VOR is our primary means of stabilizing our vision during head movement, particularly at higher frequencies above 2 Hertz. Recall that, through the VOR, the central nervous system generates eye movements that are equal in magnitude but opposite in direction to a given head movement. We measure the integrity of the VOR by its gain, which is typically calculated as eye velocity divided by head velocity. A perfect VOR gain is 1.0. The VOR does not act alone, rather, the smooth pursuit system and optokinetic reflexes can augment or enhance the VOR, depending on the movement dynamics.

As we know, damage to the VOR pathway reduces VOR gain and, in turn, degrades gaze stability, often requiring compensatory saccades, which are rapid eye movements that correct gaze position errors. Evidence demonstrates that, on average, VOR gain can be normal in people with MS,(2) but many adults with MS have severely abnormal VOR gain.(3) Further, patients with MS have been shown to have unique abnormalities in compensatory saccades, and some patients show evidence of occult internuclear ophthalmoplegia that is detectable with the video head impulse test (VHIT) but not during the standard bedside examination.(4) Indeed, studies of persons with medial longitudinal fasciculus lesions of various etiologies demonstrate characteristic patterns of reduced VOR gain on a six-canal VHIT.(5) Additionally, there is clear evidence for abnormalities on ocular vestibular evoked myogenic potentials (VEMP) in people with MS who have internuclear ophthalmoplegia, which makes this test a measure of medial longitudinal fasciculus integrity.(6) For persons diagnosed with CANVAS, one of the cardinal features is bilateral vestibular hypofunction or areflexia as measured by VOR gain.(7) Finally, VOR gain has been shown to be equivalent for persons with AD and healthy, matched controls,(8) but VOR gain is positively associated with balance in those with AD.(9)

Vestibulospinal Reflex (VSR)

As we know, the VSR stabilizes the body during movement. For example, when we are standing on a train that is turning, the head and body lean laterally opposite to the turn, activating the semicircular canals and otoliths. Signals from cranial nerve VIII and vestibular nuclei increase output through the medial vestibulospinal tract and lateral vestibulospinal tract, sending inhibitory signals to contralateral flexors and excitatory signals to ipsilateral extensors to maintain balance.

As part of the VSR, the vestibulocolic reflex stabilizes the head in space and protects it during falls or impacts. If we begin falling backward, the medial vestibulospinal tract processes signals from the utricle, saccule, and vertical semicircular canals, which trigger inhibitory signals to posterior neck extensors (e.g., splenius capitis, semispinalis capitis) and excitatory signals to anterior neck flexors (e.g., rectus capitis anterior, sternocleidomastoid). This reflex ensures coordinated muscle activity to protect the head.

There is considerable evidence for brainstem involvement and altered function in the utriculo-ocular and sacculo-colic pathways in people with MS, and many different types of abnormalities have been reported on both ocular and cervical VEMP.(10) On the other hand, VEMP results vary considerably in patients with CANVAS and further evidence is needed to determine its usefulness in this population.(11) With regard to persons with dementia, a recent systematic review suggests that VEMP testing may be useful for discriminating healthy adults from those with mild cognitive impairment and AD.(12)

The Vestibulocortical System

The vestibular system utilizes at least two major ascending pathways through the thalamus, playing a critical role in spatial awareness and motion perception. The anterior pathway originates in the vestibular nuclei and projects to the nucleus prepositus and supragenual nucleus, continuing to the anterior dorsal thalamus via the head direction network. This pathway appears to be crucial for establishing a sense of heading as we move through space. The posterior pathway links the vestibular nuclei to the ventral posterior lateral nucleus of the thalamus, and it is believed to facilitate self-motion perception and action.

Cells in regions such as the thalamus, hippocampus, entorhinal cortex, and subiculum are interconnected with these pathways, and vestibular processing in these areas contributes to spatial skills. It is well documented that vestibular loss is associated with significant reductions in hippocampal (13) and gray matter volume.(14) Further, lesions in these areas can lead to impairments in spatial memory, orientation, and navigation, emphasizing their importance in higher-order vestibular functions.(13)

The basal ganglia also play a role in processing vestibular inputs. Research using pre-surgical intra-cranial electrical brain stimulation has shown that vestibular sensations can be elicited in areas such as the ventromedial putamen, dorsolateral putamen, and external globus pallidus.(15) As clinicians, when we think of the basal ganglia, our thoughts turn towards Parkinson's disease and related conditions. There is meta-analysis support for altered ocular VEMP in persons with Parkinson's disease, which suggests brainstem involvement in addition to basal ganglia lesions.(16) Further, vestibular function tests may be useful in aiding the differential diagnosis of Parkinson's disease from MSA(17) or PSP.(18)

A systematic review recently documented 131 cases of illusory self-motion perception (excluding vertigo and dizziness) triggered by intra-cranial brain stimulation across diverse sites.(19) Two cortical targets of vestibular afference are the peri-insular vestibular cortex and area 7. The peri-insular vestibular cortex integrates multisensory input, and damage here can lead to vertigo, unsteadiness, and disruptions in visual vertical perception. In area 7, neurons respond to both optic flow and vestibular motion, and lesions in this region can cause spatial disorientation and confusion in spatial awareness. These findings underscore the vestibular system's broad impact, not only on perception and spatial orientation but also on the integration of sensory inputs across multiple brain regions, ensuring accurate navigation and maintenance of balance in complex environments.

Evidence suggests that there is a high prevalence of vestibular hypofunction in persons with mild cognitive impairment and those with AD.(20) Additionally, there appears to be a dose-response relationship between vestibular loss and cognitive status. Thus, vestibular loss may contribute to cognitive decline. Regarding CANVAS, new data from persons with the genetic variation associated with this condition suggests that we should begin to think of this disorder as one that involves not only the cerebellum, but also the sub-cortical and cortical regions as well. A recent study found widespread and symmetric cerebellar and basal ganglia atrophy, volumetric reduction in the brainstem, and limited changes in the deep cerebral white matter, such as the corpus callosum and deep tracts.(21) Thus, as vestibular physical therapists, we must consider how to accommodate or address impaired cognitive function when prescribing interventions.

CONCLUSION

The central vestibular system integrates sensory inputs across brainstem, cerebellar, subcortical, and cortical regions to regulate balance, gaze stabilization, spatial orientation, and navigation. Damage to these structures often leads to significant deficits in individuals with neurodegenerative disorders. As we will see in through the cases that follow, the available evidence suggests that physical therapy can mitigate these impairments, though clinical guidelines for vestibular rehabilitation in neurodegenerative conditions are lacking. As vestibular physical therapists, we can leverage our knowledge of neuroanatomy, neurophysiology, and the effects of neurodegenerative conditions on vestibular function to develop evidence-informed interventions for our patients. In doing so, we must remain cognizant of the fact that the targets of vestibular afference are widespread throughout the nervous system.

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Vestibular Rehabilitation and Cognitive Impairment: A Strength-Based Case Report on Alzheimer's Disease

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ABSTRACT

Introduction: This article examines the relationship between vestibular function and cognitive impairment, with a particular focus on Alzheimer Disease (AD). The intricate connections between vestibular function and higher-order cognitive processes such as spatial cognition, memory, and attention through the framework of the vestibular-cortical network are reviewed. Evidence linking vestibular dysfunction to cognitive decline and neurodegeneration highlights the hippocampus as a key neuroanatomic connection between vestibular impairment and AD pathology. Despite compelling associations, vestibular rehabilitation remains underutilized in this population, with less than 1% of individuals with AD referred for vestibular rehabilitation. **Case Description:** An 81-year-old woman with mild-moderate cognitive impairment who received an 8-week modified vestibular rehabilitation program. **Intervention & Outcomes:** Using personalized strategies like meaningful exercise targets, music tempo-matched head movements, and a strength-based framework, the program improved gait speed, balance, and mobility. These modifications enhanced patient engagement and compliance, underscoring the potential for tailored interventions to optimize outcomes for individuals with cognitive impairments. **Conclusion:** The central message of this article is to emphasize the potential benefits of vestibular rehabilitation for individuals with Alzheimer Disease and to raise awareness of evidence-based strategies for managing cognitive impairment during vestibular rehabilitation.

INTRODUCTION

As vestibular physical therapists, we are well acquainted with the vestibular end organ and its reflexes that shape much of our clinical practice: the beloved vestibulo-ocular reflex responsible for stabilizing our world during head motion and of course, the vestibulo-spinal reflex that maintains postural vertical with reference to gravity. But the vestibular system and its map of central projections is quite a sophisticated network. We invite you to explore a perhaps lesser-known grid of our inner ear: the vestibular-cortical network – a pathway that will serve as our vehicle for exploration. In this article, we aim to navigate the vestibular systems' central connectivity, the underlying ties between vestibular pathways and cognition, the vestibular-neurodegenerative link in Alzheimer's Disease, and the role of vestibular intervention on persons with cognitive impairment and perhaps its untapped potential.

Linking Vestibular Function and Cognition via the Vestibular-Cortical Network

Neuroimaging studies have given light to a vast cortical vestibular representation and an established means of transmission via the vestibular nuclei and their central projections.

Activity in nine key cortical regions has been identified in response to selective stimulation of the vestibular system: the parieto-insular vestibular cortex, the anterior parietal cortex, the ventral intraparietal cortex, Brodmann area 7a, 39, 40, the medial superior temporal area, the retrosplenial cortex, the hippocampus, and the parahippocampal cortex.(1) This synthesis of work has been essential in demonstrating that vestibular function is not merely reflexive; instead, it engages higher-order cortical regions involved in balance, spatial orientation, and cognitive processing.

When compared to our other senses (i.e. seeing, feeling, tasting, hearing), the vestibular system hosts a greater interaction with our feedback and feedforward software to make sense of our person's coordinates relative to the world around us: a very cognition – centric phenomenon.(2) Consider a simple trip to the grocery store for example: our brain helps us locate items, navigate tight spaces, and remember our list. Even reaching for an item on a high shelf while balancing on tiptoes relies on vestibular-cognitive integration, as the brain maintains stability and adapts postural control. Now, zoom out even further; how did you get there? When traversing the uneven parking lot, our brain constantly adjusts for the uneven surfaces ahead and underfoot, gages the distance between you and that rock next to your tire, and tapers our gait speed, cadence, and step length for a pause in momentum while reaching for the cart — all of which are products of the symbiotic vestibular - cognitive relationship that keeps us balanced and engaged.

Cognitive domains most closely linked to the vestibular cortical network include spatial cognition, attention, memory, and executive function.(3) There is a host of evidence detailing the connection between vestibular dysfunction and a loss of spatial cognitive ability, which will be the focus of this article. The synthesis of this work illustrates impairments in path integration, navigation, and spatial memory in persons with vestibular dysfunction.(5-7) Compelling findings in a longitudinal study of aging by Bigelow et al. solidify the co-occurrence of impairment in visuospatial tasks (i.e., spatial navigation and spatial memory) and vestibular disorders.(3) Yoder and Kirby published fascinating work on otoconia-deficient mice with findings connecting the otoliths to spatial memory.(4) The investigative implications of this pleads for identification of saccular/utricular – specific intervention. The future prospect of this poses an exciting question: does the potential to effectively intervene on the otoliths perhaps pave an avenue for the prevention and maintenance of cognitive decline?

Think clinically: for persons with vestibular dysfunction to land in our clinics, we are conditioned to anticipate a "dizziness" symptom profile as the classic catalyst: an external subjective visual room spin, an internal self-sensation of motion, a perception of unsteadiness perhaps. If we zoom out from a vertiginous focus given the established vestibular – cognitive link however (specifically for persons with confirmed otolithic dysfunction) it begs the question: what about spatial complaints and are we asking the right questions? For example, "are you getting disoriented in crowded stores? Do you have difficulty following directions? Have you ever forgotten where you parked your car?" Our awareness of the vestibular – cortical network demands not only a more comprehensive subjective investigation but moreover a physiologically driven intervention plan tailored to the multi-dimensional impairment domains at play.

Vestibular function in Alzheimer's Disease

The relationship between the vestibular system and cognition has sparked an investigation of a further potential pathophysiologic correlate, a vestibular – neurodegenerative link. The neuronal degeneration identified in Alzheimer's Disease (AD), for example, is associated with phylogenetically older neurons and is characterized by cognitive decline and neurodegeneration, including beta-amyloid deposition and neurofibrillary tangles.(5) AD is clinically recognized for its multidimensional cognitive breakdown; however, recent investigation has given rise to a subset of behavioral characteristics and their pathophysiologic substrates. Data suggests that up to a third of persons with newly diagnosed AD describe spatial disorientation, and 47% of patients with AD have suffered a fall.(6) A recent meta-analysis on fall risk in AD cites a 44.27% risk of falls for elderly persons with AD compared to healthy controls.(7)

For your clinical consideration, falls have been suggested to precede detectable cognitive change in the preclinical disease process of AD (8), which places vestibular therapists at the unique forefront of early detection and, perhaps, preventative management opportunities. More specifically, a direct link between vestibular dysfunction and the disease process of AD is becoming increasingly evident. Wei et al. identified a staggering three-to-four-fold increase in the probability of vestibular dysfunction in persons with AD, which has sparked the exploration of vestibular testing as a potential avenue for early dementia screening.(9) Harun et al. estimate an impressive 50% likelihood of a vestibular hypofunction in persons with AD.(10) The proposed underlying tie? The hippocampus. Known for its role in memory and spatial storage, the hippocampus is gaining attention as the shared conduit between the disease process of AD and vestibular dysfunction. It has been identified as the first region of the brain to degenerate in the disease course of AD and has been found to be significantly atrophied in patients with chronic bilateral vestibular loss when compared to healthy controls(11), implicating the hippocampus as the likely neuroanatomic common thread.

Integrating Rehabilitation Principles for Individuals with Cognitive Impairment

Rehabilitation for individuals with cognitive impairment, particularly those living with dementia, requires a nuanced approach that emphasizes remaining abilities rather than deficits. A strength-based perspective can create meaningful opportunities for recovery and improve quality of life. By tailoring interventions to an individual's strengths and fostering a sense of agency, physical therapists can support functional gains. This approach involves structured motor learning techniques like errorless learning and spaced retrieval to reduce cognitive load and promote successful task performance, particularly in activities of daily living. Simplified, consistent practice enhances motor behaviors and functional independence. Additionally, creating a safe, predictable environment with minimal distractions and clear communication fosters engagement and builds trust. For example, reducing environmental noise and ensuring familiar routines can significantly enhance participation. Research has shown that individuals with AD can improve balance and mobility when interventions are delivered with a motor learning-forward framework.(12) By combining person-centered care, targeted strategies, and environmental adjustments, therapists can help patients achieve meaningful improvements in physical and cognitive function.

Role of vestibular therapy for people with Alzheimer's Disease

With an extensive 801 data point synthesis, Gandhi et al. conducted a retrospective chart review of individuals managed for AD over the course of a year. Despite the prevalence of fall risk and vestibular dysfunction in this patient population, only 6% of those individuals were referred to physical therapy, and a staggering 0.6% were referred to vestibular therapy.(13) We could speculate on several barriers to this gross underutilization of resources, and though likely multifactorial, a bias against and/or a misunderstanding of an individual's rehabilitative potential with cognitive impairment is a likely culprit.

Considering these factors, our team hypothesized that modifications might optimize benefits of vestibular rehabilitation for people with cognitive impairment. Our team applied Strength-Based Approach principles to the vestibular rehabilitation clinical practice guidelines to propose modifications to leverage those with cognitive impairment who are participating in vestibular rehabilitation.(14) In the theoretical framework for providing vestibular rehabilitation to individuals with cognitive impairments, Klatt et al. suggest modifications for balance, endurance, habituation, and gaze stabilization exercises that focus on enhancing motor learning and engagement. The following examples illustrate how these modifications can be implemented into clinical practice.

For gaze stabilization interventions, exercises begin in low-distraction environments, such as plain backgrounds with minimal visual or auditory input, and progress to real-life or simulated settings like virtual simulations or meaningful locations such as the home or a grocery store. Meaningful fixation targets, such as photos of loved ones, pets, or objects associated with positive memories, are used to enhance engagement. Associating specific head movements with emotional contexts, like nodding "yes" to a positive image, further increases relevance and motivation. Errorless learning strategies minimize mistakes by providing brief, rhythmic, and consistent verbal cues, such as “look at the target” or “nod yes,” and using physical guidance or tactile cues when necessary to ensure correct execution. Procedural learning is emphasized through implicit instruction and functional tasks, enabling patients to "learn by doing." Intensity dosage is tailored to each individual by monitoring for signs of mental fatigue, such as eye squinting or facial tension, and incorporating frequent breaks as needed. Perceptual and sensory priming, such as playing calming or enjoyable music or introducing familiar scents, enhances comfort and focus during exercises. Caregiver involvement is encouraged to reinforce learning, monitor for discomfort, and ensure safety during home practice, creating a supportive and effective approach to gaze stabilization. In addition to modifications for gaze stabilization, the article outlines modifications for balance training, habituation exercises, and walking for endurance to enhance the effectiveness of vestibular rehabilitation in individuals with cognitive impairments.(14) Across all exercise categories, strategies like procedural learning, errorless learning, appropriate dosing of intensity, and caregiver involvement ensure that individuals with cognitive impairments can participate meaningfully and safely in vestibular rehabilitation.(14)

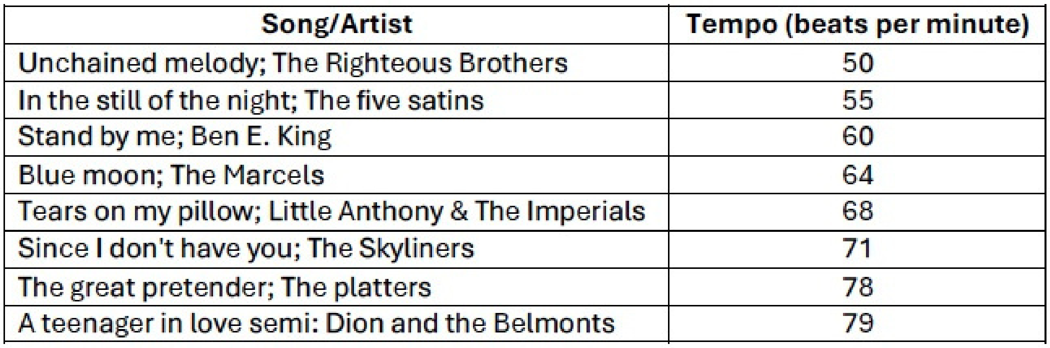
In integrating these strategies, vestibular rehabilitation can be modified to meet the needs of people with cognitive impairment by fostering engagement, minimizing frustration, and optimizing functional improvements. The following clinical case illustrates a strength-based approach in practice, showcasing how cognitive-based modifications can be effectively integrated into vestibular rehabilitation. This approach demonstrates the impact of person-centered, tailored interventions on both physical and cognitive outcomes in a patient with vestibular dysfunction and cognitive impairment.

CASE STUDY

This case highlights an 81-year-old female with mild-moderate cognitive impairment (Mini Mental Status Examination = 20/30 and Montreal Cognitive Assessment = 17/30) who received vestibular rehabilitation with modifications to leverage capabilities. The patient denied dizziness at baseline but clearly exhibited dizziness during head movements, as indicated by positive findings on the bedside head impulse test and visible discomfort during vestibulo-ocular reflex (VOR) activity. During the pre-training interview, it was revealed that the patient did not have a specific music genre preference but responded positively to songs from the 1950s and 1960s. She expressed a fond memory of the beach as a preferred target for the VOR pitch exercise and a strong aversion to liver and onions, which was used as a target for the VOR yaw exercise.

The rehabilitation program consisted of 8 weekly sessions, each lasting 45 minutes. Each session included gait training, endurance training (dynamic standing therapeutic exercises), balance training (static and dynamic standing activity on varying surfaces with eyes open and closed), and gaze stability training (VORx1 in yaw and pitch planes). Initially, the head movement speed for gaze stability training was set at 60 bpm for the first three sessions, then increased to 70 bpm in sessions 4-8. Attempts at 80 bpm led to dizziness and resistance, so the speed was adjusted accordingly. Modifications in the rehabilitation protocol included in-home training, meaningful targets for VOR exercises, and the use of music to prime head movements. The music tempo was matched to the

Table 1. Songs used during VORx1 yaw and pitch exercise to achieve desired head speeds.



Song/Artist	Tempo (beats per minute)
Unchained melody; The Righteous Brothers	50
In the still of the night; The five satins	55
Stand by me; Ben E. King	60
Blue moon; The Marcels	64
Tears on my pillow; Little Anthony & The Imperials	68
Since I don't have you; The Skyliners	71
The great pretender; The platters	78
A teenager in love semi: Dion and the Belmonts	79

desired head movement speed, and the patient listened to popular songs from the 50s and 60s (See Table 1 for songs used in this case). Short, concise verbal cues were used, such as "Do you like liver and onions? Shake your head no," for VOR yaw and "Do you like the beach? Nod your head yes," for VOR pitch. Music was also played during gait, balance, and endurance exercises for enjoyment (“Golden Oldies” radio station on Pandora).

Baseline and post-training assessments revealed improvements in functional measures. Gait speed increased from 0.49 m/s pre-training to 0.67 m/s post-training. The 5 Times Sit-to-Stand Test improved from 24.5 seconds to 22.1 seconds, and the Timed Up and Go test improved from 16.9 seconds to 13.1 seconds. These results indicate a positive outcome in terms of functional mobility, although the rehabilitation dose (1x/week) and the lack of a home exercise program may have limited the overall effectiveness of the intervention.

This case highlights the potential benefits of incorporating cognitive-based modifications into vestibular rehabilitation, such as meaningful targets and environmental adjustments, to enhance patient engagement and improve outcomes. However, the frequency of the sessions and the absence of caregiver support for home exercises may have hindered the maximum potential benefits of the intervention. Future research should explore the effectiveness of higher-frequency sessions, the integration of caregiver participation, and the broader impact of cognitive-based modifications on vestibular rehabilitation for older adults with cognitive impairments. This case suggests that personalized interventions, such as incorporating meaningful memories and music, could be an effective strategy to improve the rehabilitation experience and outcomes for older adults with vestibular dysfunction.

CONCLUSION

This case demonstrates the potential of cognitive-based modifications to enhance vestibular rehabilitation outcomes for individuals with cognitive impairments. An 81-year-old woman with mild to moderate impairments showed improvements in gait speed, five-time-sit-to-stand time, and the Timed Up and Go test after 8 weeks of weekly vestibular rehabilitation. Modifications, including personalized targets, music-matched tempos, and in-home training, boosted her engagement and compliance. While exercise intensity during sessions was appropriate, the program was underdosed due to the weekly frequency and lack of home exercise. Adherence to home programs may require caregiver support to ensure consistent practice and assist with modifications.

The vestibular-cortical network, which links vestibular function with higher-order cognitive processes such as spatial cognition, memory, and attention, provides a compelling framework for understanding how vestibular rehabilitation can support not only physical but also cognitive function. Neuroimaging studies have revealed that the vestibular system engages various cortical regions involved in balance and spatial orientation, highlighting the integral role of vestibular processing in cognitive tasks. This case demonstrates how a tailored approach to rehabilitation, incorporating the patient's cognitive preferences and leveraging the vestibular-cortical network, can optimize outcomes for individuals with cognitive impairments.

Furthermore, the relationship between vestibular dysfunction and cognitive decline, particularly in neurodegenerative diseases like Alzheimer's, is gaining attention. This case underscores the importance of a person-centered approach, where rehabilitation emphasizes the patient's strengths, fosters a sense of agency, and adapts the therapeutic environment to support functional gains. By tailoring interventions to the individual's remaining abilities and incorporating cognitive strategies, vestibular physical therapists can play a critical role in improving quality of life and preserving functional independence for individuals with cognitive impairments and neurodegenerative diseases. Vestibular dysfunction is gaining recognition as a potential early indicator of cognitive impairment; early vestibular intervention may offer a unique opportunity for not only early detection but perhaps the prevention of further cognitive decline and the optimization of functional recovery.

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Vestibular Dysfunction and Vestibular Rehabilitation for People with Multiple Sclerosis

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ABSTRACT

It is well-recognized that multiple sclerosis (MS) can cause lesions in the vestibular nuclei or other parts of the central vestibular pathways. These lesions can result in problems such as oscillopsia, dizziness, difficulty controlling the vestibulo-ocular reflex (VOR), postural instability, and even recurrent falls. Prior studies demonstrate that people with MS (PwMS) often have semicircular canal and otolith pathways dysfunction, abnormal compensatory oculomotor behaviors, impaired sensory organization for postural control, gait ataxia, and altered perception of vertical. Evidence also suggests that vestibular rehabilitation is effective for PwMS, including those with mild, moderate, and severe disease. Herein, we discuss the clinical relevance of the literature related to vestibular dysfunction and the application of vestibular rehabilitation for PwMS. Additionally, we present a case study that illustrates the successful delivery of patient education, therapeutic exercise, neuromuscular re-education, balance, and gait training in a 26-year-old patient with an acute exacerbation of MS. Taken together, there is clear evidence to support vestibular rehabilitation for PwMS.

INTRODUCTION

When someone with multiple sclerosis (MS) has lesions in the vestibular nuclei or other parts of the central vestibular pathways, it can lead to problems like oscillopsia, dizziness, difficulty controlling the vestibulo-ocular reflex (VOR), postural instability, and even recurrent falls.(1-4) Dizziness and balance issues are common for people with MS (PwMS), which is why it's so important for us as physical therapists to be prepared to address these vestibular challenges.

In a large study, Marrie and colleagues found that about 75% of people with MS reported some degree of disability due to dizziness or balance problems, as measured by the Dizziness Handicap Inventory (DHI).(5) In their study, the disability due to dizziness was rated as mild in 61%, moderate in 26%, and severe in 13% of people who answered at least one question with "sometimes." The most common triggers for dizziness or imbalance in this study were things like quickly turning the head, bending over, and looking up. Interestingly, they also found that people with higher socioeconomic status (e.g., higher education, income, and insurance status) were less likely to report moderate or severe dizziness. Additionally, PwMS who reported more disability on the Patient Determined Disease Steps scale were also more likely to have moderate or severe dizziness, with those reporting moderate disability having the highest odds. This highlights the importance of addressing dizziness and balance challenges in our treatment plans for PwMS.

Vestibulo-ocular Reflex and Oculomotor Abnormalities

Degirmenci and colleagues discovered that PwMS show various abnormal findings on electronystagmography (ENG).(6) In fact, 83% of PwMS had issues with oculomotor subtests, and those with abnormal caloric test results also had abnormal oculomotor subtests. Interestingly, even PwMS who did not report vestibular symptoms, and those with a normal neuro exam and no brainstem or cerebellar lesions on imaging, still had at least one abnormal finding on ENG.

The only data on rotational chair testing for PwMS comes from Cochrane and colleagues, who performed a comprehensive vestibular assessment in patients with relapsing-remitting MS.(7) Their study showed that while the VOR gain was similar between PwMS and controls, PwMS had significantly altered VOR cancellation.

In another study, Manago and colleagues looked at computerized versions of the gaze stabilization test (GST) and the dynamic visual acuity (DVA) test.(2) They found that PwMS had difficulties with gaze stabilization. When comparing PwMS with healthy controls, they found that PwMS had slower head movement velocity during the GST and poorer visual acuity during the DVA test. Notably, those with higher disability had slower head movements during the GST, but their visual acuity was like those with lower disability.

Garg and colleagues also examined gaze stabilization in PwMS at fall-risk and age-matched controls, looking at a range of factors like VOR gain, compensatory saccades (CS), and various functional measures.(3) Their study showed that VOR gain in the lateral canal was normal on average but that PwMS had to rely on CS more frequently than controls. However, the variability in VOR gain was higher in PwMS, making it clear that it is important to examine individual data.

Several earlier studies using the video head impulse test (vHIT) also suggested that VOR gain might be lower in PwMS compared to controls.(8-10) However, overall VOR gains for PwMS were still above the threshold for what is considered abnormally low. More recent studies, though, show that individuals with lesions in the medial longitudinal fasciculus may experience characteristic patterns of reduced VOR gain, which could complicate the interpretation of vHIT findings.(11,12)

Loyd and colleagues were the first to present data from a six-canal vHIT in a larger group of PwMS.(13) They found that a significant proportion of their sample had abnormal VOR gains across all canals. In addition, PwMS performed more than 2.5 times worse than healthy controls on DVA testing. This raises a big question—what is going on with these patients? It seems that the picture for PwMS regarding vestibular function is more complex than we initially thought.

CS play a key role in helping stabilize vision during head movements, and PwMS often show abnormalities in this function. Grove and colleagues have extensively researched oculomotor behavior in PwMS using data from the baseline visit of a randomized control trial comparing two types of interventions.(14) In their first study, they found notable differences between PwMS and a comparison group with unilateral deafferentation. Specifically, PwMS tended to recruit fewer, earlier, and smaller CS compared to the deafferented group.(15) Building on this work, Grove and colleagues showed people with moderate MS had VOR gains that were like those seen in individuals who had a vestibular schwannoma removed.(16) Interestingly, many PwMS produced unique compensatory eye movements in response to head impulses, such as needing to adjust eye position after an over-compensatory saccade. Some PwMS failed to generate CS to stabilize vision, which suggested occult internuclear ophthalmoplegia. By analyzing six-canal vHIT data, Grove and colleagues found that those with more severe MS-related disability had lower VOR gains and larger gaze position errors for all semicircular canals.(17) This study provided strong evidence that PwMS with greater disability have more significant vestibulo-oculomotor dysfunction. Most recently, Grove and colleagues showed that, in PwMS, compensatory gaze stabilization was less effective in response to vertical head impulses compared to horizontal ones.(18) These findings are important for vestibular rehabilitation, as gaze stability exercises are designed to facilitate CS and help reduce oscillopsia. If vertical CS are particularly affected in PwMS, this could have implications for the effectiveness of gaze stability exercises.

So, why does all this matter? CS are a crucial part of how the brain stabilizes vision, and when they are not functioning properly, it could make it harder for PwMS to recover gaze stability, particularly if their VOR gains are low. For these patients, physical therapists may need to focus on alternative strategies to minimize oscillopsia, such as slowing down head movements to reduce gaze position errors and offering personalized gaze stability training that emphasizes vertical head movements.

Otolith Pathway Test Results

When it comes to vestibular function tests, the data on vestibular evoked myogenic potentials (VEMP) in PwMS can be a bit tricky to interpret. There is quite a bit of variation in the findings, which is partly why the results are not always straightforward. Both cervical and ocular VEMP tests have shown a range of abnormalities in PwMS. These can include things like absent waves on one or both sides, prolonged latencies, and reduced or increased wave amplitudes.(19,20) The most often reported VEMP abnormalities are absent responses in cervical VEMP and prolonged latencies in ocular VEMP. In fact, some studies even suggest that VEMP responses are abnormal in all PwMS subjects. However, it is interesting to note that, even when cervical VEMP results come out normal, ocular VEMP might still show abnormalities. This variation makes interpreting VEMP data in PwMS more complicated compared to other vestibular function tests.

Posturography Findings

There have been several reports of abnormalities on posturography in PwMS. In one older study by Jackson and colleagues, PwMS took part in the Motor Control, Adaptation, and Sensory Organization Test (SOT) components of posturography.(21) The study included adults with mild MS. The results showed that 80% of PwMS had at least one abnormal latency on the motor control test, 88% had at least two abnormal trials on the adaptation test, and 68% had at least one sensory abnormality, although there was not a clear pattern to the sensory findings.

In another study, Nelson and colleagues examined PwMS who underwent computerized dynamic posturography.(22) The participants were grouped into high-function and low-function categories based on their functional status. They found that 30% of the high-function group showed abnormal posturography results, but few had signs of a vestibular pattern. On the other hand, 58% of the low-function group had abnormal posturography results, and most of them had a vestibular pattern. So, while postural control issues are common in PwMS, they vary greatly between individuals.

Vestibular Gait Ataxia

When it comes to how the vestibular system affects gait, Forsberg and colleagues found that PwMS had the most difficulty with tasks involving horizontal and vertical head turns while performing the Dynamic Gait Index (DGI).(23) They studied PwMS with self-reported gait and balance problems who were able to walk 100 meters. They found that PwMS who had experienced falls scored significantly lower on the DGI compared to those who had not fallen. In fact, the DGI had an 87% sensitivity for identifying fallers, with a cutoff score of ≤ 19/24. In a separate study, Forsberg and colleagues assessed PwMS and found that their median score on the Functional Gait Assessment (FGA) was 15, with the greatest difficulty with tasks like walking with head turns, tandem gait, and walking with eyes closed.(24)

Impaired Orientation

Verticality, or the sense of upright orientation, can also be affected in PwMS. Jackson and colleagues found that, when compared to age- and sex-matched controls, PwMS made larger errors when estimating both vertical and horizontal alignment.(21) Their results were more likely to be abnormal when the test was done with the head tilted to the side. In fact, 11% of subjects had normal results in all positions, but 67% had normal results only when their head was held upright.

Similarly, Cochrane and colleagues showed that even in PwMS with less impairment, the subjective visual vertical was more variable compared to healthy controls.(7) This suggests that the sense of verticality in PwMS can be unreliable or unstable.

Finally, Klatt and colleagues explored whether subjective visual vertical might relate to balance and functional abilities.(25) In their study, PwMS completed several tests, including the subjective visual vertical test with a distractor (rod and frame test), the Barthel Index, the Berg Balance Scale (BBS), gait velocity, and a few others. They found that a less accurate subjective visual vertical, when tested with the distractor frame, was significantly associated with poorer balance performance. This indicates that PwMS who struggle with balance might rely more on visual cues from their environment, highlighting the potential for interventions aimed at adjusting how they use sensory information for balance.

CASE STUDY

The following case demonstrates how vestibular problems manifest in PwMS and how physical therapy (PT) can be helpful. Ben is a 26-year-old male, living with his mother in a two-story home and working as a data analyst. He works a hybrid schedule, three days at the office and two days at home. He was diagnosed with primary progressive MS two years ago. During this time, he remained independent in functional mobility, and he reports that his only limitations were long distance walking (more than three miles) and difficulty walking on sand at the beach. He did not have a regular exercise program other than walking his dog approximately one mile daily.

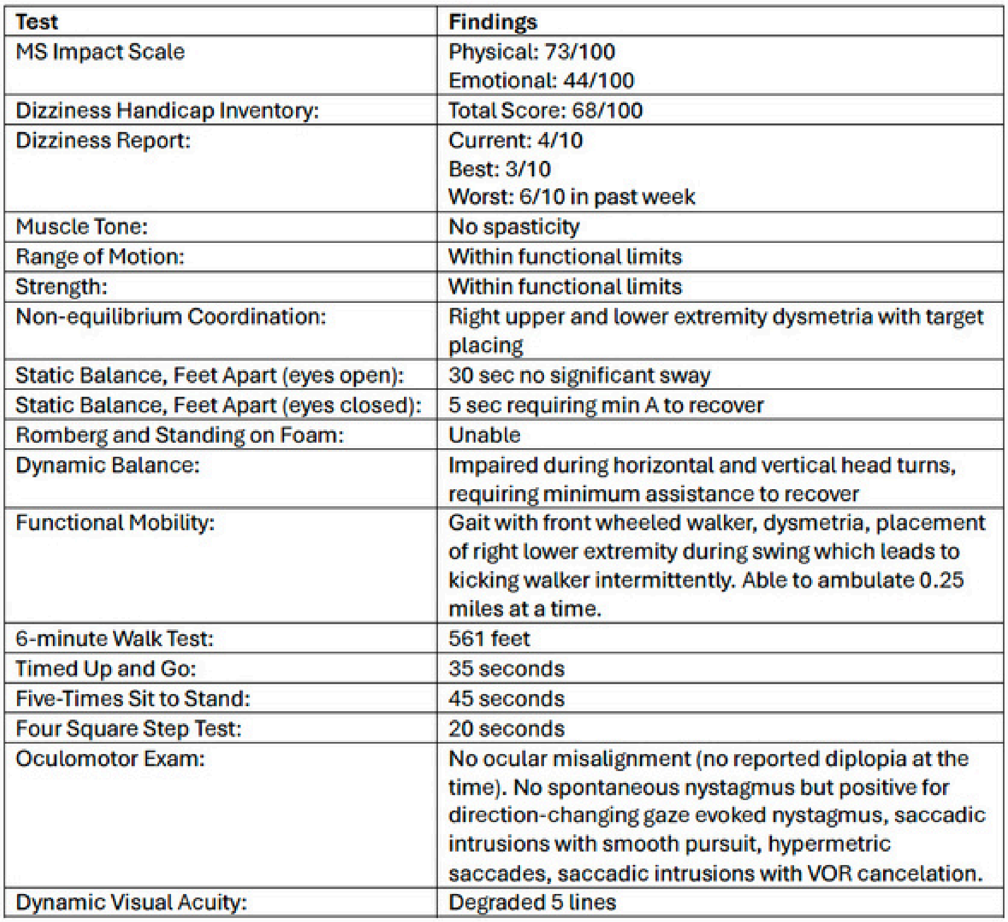
Ben developed significant changes in his balance five months ago. He reported running into walls and some intermittent double vision. Ben lost his balance and fell while walking his dog six weeks ago. He was transported to the emergency room when he had difficulty returning to stand, and imaging showed two cerebellar lesions: one at the cerebellar vermis and the other in the right hemisphere. Ben subsequently underwent intravenous steroid infusions and then an inpatient admission for plasmaphoresis, both of which made little change to his function. He was referred to outpatient PT following his hospital admission. Upon his initial evaluation, Ben reported his current limitations as the inability to drive, intermittent diplopia, uncoordinated right arm and leg movement (difficulty shaving, grooming, eating, walking with a walker), difficulty negotiating stairs, sit to stand and opening/shutting doors. He reports difficulty with slurring words, especially with fatigue, but no trouble swallowing. He is currently on medical leave. Ben also reported symptoms of dizziness intermittently with rapid movement, imbalance and incoordination, fatigue and occasionally feeling weak if very tired. The results of his initial evaluation are reported in Table 1.

Intervention:

Ben was given the following recommendations for functional mobility. First, he was to use an alternate rollator walker with “slow walking” brake to enable more control and mobility on uneven surfaces. Second, he was prescribed stationary biking x 10 minutes initially, working up to 20 minutes on non-therapy days. As his endurance improved, he started short distance dog walking with his mother to enable him to begin to return to his role as a pet owner. Ben was provided education regarding pacing, compensatory strategies for symptom control, the role of sensory organization in balance, and the etiology of dizziness and coordination impairments.

He worked on proximal control and eye/head/hand coordination. For example, he practiced kneeling and ½ kneeling with reaching with Blazepods, encouraging visual scanning and dual-task with color choices. He also worked on quadruped exercises and kneeling at home. He performed sit to/from standing without upper extremity support, incorporating reaching towards the ceiling while looking up at his hands with each stand. Ben performed gaze stability

Table 1. Initial Evaluation Findings



Test	Findings
MS Impact Scale	Physical: 73/100 Emotional: 44/100
Dizziness Handicap Inventory:	Total Score: 68/100
Dizziness Report:	Current: 4/10 Best: 3/10 Worst: 6/10 in past week
Muscle Tone:	No spasticity
Range of Motion:	Within functional limits
Strength:	Within functional limits
Non-equilibrium Coordination:	Right upper and lower extremity dysmetria with target placing
Static Balance, Feet Apart (eyes open):	30 sec no significant sway
Static Balance, Feet Apart (eyes closed):	5 sec requiring min A to recover
Romberg and Standing on Foam:	Unable
Dynamic Balance:	Impaired during horizontal and vertical head turns, requiring minimum assistance to recover
Functional Mobility:	Gait with front wheeled walker, dysmetria, placement of right lower extremity during swing which leads to kicking walker intermittently. Able to ambulate 0.25 miles at a time.
6-minute Walk Test:	561 feet
Timed Up and Go:	35 seconds
Five-Times Sit to Stand:	45 seconds
Four Square Step Test:	20 seconds
Oculomotor Exam:	No ocular misalignment (no reported diplopia at the time). No spontaneous nystagmus but positive for direction-changing gaze evoked nystagmus, saccadic intrusions with smooth pursuit, hypermetric saccades, saccadic intrusions with VOR cancelation.
Dynamic Visual Acuity:	Degraded 5 lines

and gaze shifting for visual scanning. For this he incorporated gaze shifting from a paper on the table to a computer monitor to mimic work requirements.

He was prescribed VOR x 1 (standing with upper extremity support), initially 30 seconds, 3x/day, then increased to 60 seconds, 3x/day. Over time, he Progressed to VOR x 1 without upper extremity support, with improved speed and duration. He often reported dizziness at 4-5/10 with VOR x 1; so, he was never able to progress to more than 3x/per day.

For habituation, he was encouraged to make head turns and reach with other activities, which also addressed motion sensitivity. Additionally, he performed squats to reach to the floor, which addressed his goal of cleaning up after his dog. He was prescribed VOR cancellation in sitting and then progressed to standing, using both upper extremities to encourage dissociation of upper/lower trunk.

His program included coordination/control exercises. For example, he did ball toss with a large six-pound weighted ball (larger was easier for control) in the clinic and at home with his mother. He used a rebounder with a seven-pound ball. Ben also performed toe tapping on/off a step with Blazepods (paper targets at home). He progressed four square stepping to dual task conditions, holding objects or cognitive task (e.g., math problems, favorite movies with plot description).

Finally, we incorporated sensory organization training. This included eyes open/closed alternating every 10 seconds, initially. He worked on eyes closed x 30-45 seconds with weight-shifting. Ben also practiced standing on foam eyes open with weight-shifting and eyes closed for 5-10 seconds at a time.

Ben was seen 2x/week for a total of 20 visits over 11 weeks. He reported much improved overall balance, less dizziness and a little better coordination. He reported less fatigue and as a result, improved ability to concentrate. He saw a neuro-opthalmologist who did not recommend changing his corrective lenses as his diplopia was improving. Ben was able to return to part-time work at home, but he has not yet returned to driving. He continues to walk his dog with rollator walker and with his mother supervising in case of his dog misbehaving. Ben reported good compliance with exercise at home. He was discharged at this point, but with the intention of returning quarterly for monitoring and to revise his home program. Ben's outcomes are reported in Table 2.

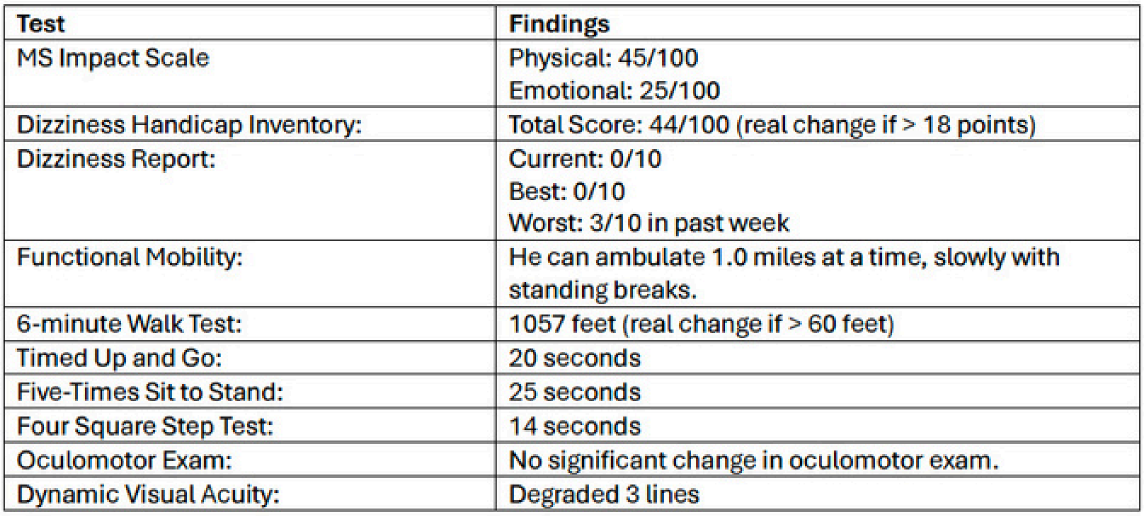
Discussion

This case demonstrates the importance of the cerebellum, specifically the cerebellar vermis, in central vestibular function. Ben had good resources that allowed for home stationary bike, a supportive family to assist as needed, and consistent transportation. His intervention was limited at times due to fatigue and the duration of symptom provocation during therapy sessions. The outcomes from this case are consistent with those that have been reported in the literature. Ben was challenged by eye/head coordination and gaze stability but improved with longer duration of care. He was able to return to his life roles as data analyst and pet owner, albeit limited due to his impairments. He did have an improvement in gaze stability but no change in other oculomotor impairments. He reported improved diplopia, but this was not directly addressed in PT.

Hebert and colleagues were the first to provide solid evidence from a randomized controlled trial (RCT) comparing vestibular rehabilitation with a control group, which in this case, also included a waitlist group.(26) The study involved PwMS who were randomly assigned to one of three groups: an experimental group receiving standardized vestibular rehabilitation, an exercise control group performing bicycle endurance and stretching exercises, and a waitlist group receiving usual care. Outcomes were measured using a variety of tools: the MFIS, posturography, the six-minute walk test, DHI, and the Beck Depression Inventory-II. After the six-week intervention, the vestibular rehabilitation group showed significantly greater improvements in fatigue, balance, and disability due to dizziness compared to the exercise control group and the waitlist group. However, at the four-week follow-up, although there were trends toward regression in several outcomes, the only statistically significant change was that the waitlist control group reported higher levels of depression. This suggests that while vestibular rehabilitation offers immediate benefits, some form of maintenance is necessary to help PwMS retain these gains.

Cattaneo and colleagues examined whether balance exercises with specific sensory challenges, such as eyes closed on foam, would improve balance and transfer to other sensory conditions.(27) They

Table 2. Final Evaluation Findings



Test	Findings
MS Impact Scale	Physical: 45/100 Emotional: 25/100
Dizziness Handicap Inventory:	Total Score: 44/100 (real change if > 18 points)
Dizziness Report:	Current: 0/10 Best: 0/10 Worst: 3/10 in past week
Functional Mobility:	He can ambulate 1.0 miles at a time, slowly with standing breaks.
6-minute Walk Test:	1057 feet (real change if > 60 feet)
Timed Up and Go:	20 seconds
Five-Times Sit to Stand:	25 seconds
Four Square Step Test:	14 seconds
Oculomotor Exam:	No significant change in oculomotor exam.
Dynamic Visual Acuity:	Degraded 3 lines

studied PwMS who were mildly to moderately disabled and assessed balance using the SOT. The experimental group, which received balance exercises with sensory challenges, showed improved balance in the conditions that were specifically trained. However, there were no significant differences between the groups in conditions that were not addressed in the training. This finding suggests that the benefits of balance training are specific to the conditions targeted in the program.

Birchetto and colleagues conducted a similar study where they compared personalized balance exercises based on SOT results to traditional balance exercises.(28) They studied PwMS and assessed balance using the BBS, posturography, and the MFIS. PwMS were randomly assigned to either the personalized rehabilitation program or a traditional rehabilitation approach. The personalized group showed greater improvements in both the total BBS score and the composite SOT score, with the improvements in the personalized group meeting clinically relevant thresholds. These findings indicate that personalized balance programs can provide greater benefits compared to traditional approaches.

A few years later, Ozgen and colleagues carried out an RCT of customized vestibular rehabilitation in PwMS, comparing it with a waitlist group who received usual care.(29) Both groups had mild to moderate MS-related disability. A wide range of outcome measures was used, including the Romberg Test, the Timed Up and Go Test, the DGI, and several other balance, gait, and functional measures. The vestibular rehabilitation group showed significant improvements across most of the measures, including balance, gait, and disability, whereas the waitlist group showed no significant improvements. This study further supports the effectiveness of vestibular rehabilitation for PwMS.

Tramontano and colleagues performed a similar study with hospitalized PwMS.30 They compared vestibular rehabilitation to usual care, measuring outcomes such as the Barthel Index, the Tinetti Test, the BBS, and the Fatigue Severity Scale. The experimental group showed greater improvements in balance, fatigue perception, activities of daily living, and gait compared to the control group. However, walking capacity, as measured by the two-minute walk test, did not show a statistically significant improvement. Despite this, the experimental group demonstrated large effect sizes across multiple domains, suggesting that vestibular rehabilitation has a significant positive impact on multiple aspects of health and function.

Hebert and colleagues later developed the Balance and Eye-Movement Exercises for Persons with Multiple Sclerosis (BEEMS) program, which includes vestibular-neutral exercises such as pursuit and saccades.(31) In a study of PwMS, participants in the BEEMS group showed greater improvements in the SOT composite score compared to the no-treatment control group. These improvements were sustained at 14 weeks. Notably, participants with brainstem or cerebellar lesions showed even greater improvements than those without such lesions. This suggests that vestibular training can be particularly beneficial for PwMS with certain types of lesions, and that improvements in balance and function can be achieved regardless of the presence of these lesions.

After Hebert and colleagues established that vestibular training is effective, Loyd and colleagues compared the efficacy of two evidence-based interventions: vestibular rehabilitation and strength and aerobic exercise training.(14) They enrolled adults with mild to moderate MS who had self-reported dizziness, reduced balance confidence, impaired gait stability, or more than two falls in the past year. The primary outcome measure was the DHI, and secondary outcomes included the Activities-specific Balance Confidence Scale (ABCS), computerized DVA, and the FGA. Both groups showed significant improvements in the DHI and ABCS scores, but the change in these measures over six weeks was not significantly different between the two groups. Similarly, there were no significant differences between the groups for DVA and FGA scores. The findings suggest that while both types of interventions lead to significant improvements, the difference between vestibular rehabilitation and strength/aerobic exercise training may not be substantial in terms of specific outcomes like gaze stability or postural control. However, the overall message is clear: increasing physical activity, regardless of the specific approach, helps reduce vestibular symptoms in PwMS. Yet, personalized approaches focusing on gaze and postural stability may be more effective in addressing these symptoms in the long term.

Summary

PwMS may have lesions that cause semicircular canal and otolith pathways dysfunction and that result in problems such as abnormal compensatory oculomotor behaviors, impaired sensory organization for postural control, gait ataxia, and altered perception of vertical. Vestibular rehabilitation is effective for PwMS, including those with mild, moderate, and severe disease. The case described in this article demonstrates how a thorough examination, comprehensive set of interventions, and strong patient compliance led to successful outcomes. Taken together, there is substantial evidence to support vestibular rehabilitation for PwMS. Thus, as specialist providers, we must assess for vestibular dysfunction in our patients with MS and work collaboratively with affected patients to get the best results.

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Be Sure To Stop By!
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VRSIG representatives will have a table there to discuss SIG engagements and pick up some VR SIG Swag!

When: Friday, February 14th at 6:30 pm
Check CSM website for location

Improvements in Vestibulo-ocular Reflex gain, Dynamic Balance, and Gait Speed Following Vestibular Rehabilitation in an Individual with CANVAS

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ABSTRACT

Introduction: Evidence in the literature has shown that individuals with neurodegenerative cerebellar ataxias have the potential to improve balance, coordination, and aerobic capacity with rehabilitation. Yet there is scant literature reporting the positive efficacy of vestibular physical therapy (VPT) in ataxia and even more so among individuals living with Cerebellar Ataxia with Neuropathy and Vestibular Areflexia Syndrome (CANVAS), a rare cerebellar neurodegenerative condition often influencing cerebellar, sensory, and vestibular functions. **Case Description:** This case study highlights the efficacy of VPT in a 60-year-old female with genetically diagnosed CANVAS (biallelic RFC-1 positive) who performed intensive VPT in the clinic and home setting over a two-year period. **Intervention:** Gaze and postural stability, gait training, aerobic exercise, core strengthening. **Outcomes:** Improvements or stable measures over two years including: vestibulo-ocular reflex gains via passive video head impulse testing, gait velocity, dynamic balance, clinical neurological measures, and risk for falls. **Conclusion:** This unique case report of an individual diagnosed with CANVAS, demonstrates that vestibular physiological, functional, and clinical improvements are possible with the help of intensive VPT and intensive cardiovascular exercise.

INTRODUCTION

Cerebellar ataxias are of various neurological etiologies (inherited, sporadic, or acquired) and phenotypes impacting vestibulo-ocular motor, sensory-motor, cardiovascular as well as motor learning and adaptation systems.(1-4) Individuals with ataxia may have neurological impairments that impact function such as dysmetria, dyssynergia, intention or postural tremor, imbalance, and non-motor functions (5,6) as well as vestibular and oculomotor impairments including vergence, saccade, or smooth pursuit difficulties, gaze instability and oscillopsia (without or with head movement).(7,8) In fact, 55-58% of individuals with ataxia with and without peripheral vestibulopathy have perceived symptoms of oscillopsia. Severity of oscillopsia symptoms in ataxia with head movement and with vestibular impairment may be comparable to individuals with bilateral vestibulopathy.(8,9)

Given the rarity, variety, and phenotypes of ataxia, there is limited evidence to provide guidance for rehabilitation. Available research shows positive benefits of balance and coordinative training and aerobic exercise for gait, balance, and clinical neurological measures.(10-16) Recent retrospective and case report studies show positive effects of vestibular physical therapy (VPT) for people with ataxia. A retrospective study among individuals with ataxia evaluated the efficacy of gaze, postural stability, and habituation exercises, and demonstrated improvements in balance confidence and fall risk.(17) Another retrospective study evaluated the effects of VPT for individuals with idiopathic cerebellar ataxia with vestibulopathy (iCABV) and found improvements in standing static balance, and fall risk.(18) Further, a case study of an individual with Cerebellar Ataxia with Neuropathy and Vestibular Areflexia Syndrome (CANVAS) who performed gaze and postural stability training, including use of a gaze compliance monitoring system (i.e., VestAid), showed improvements in gait speed, dynamic balance, and “eye gaze compliance”.(19) No studies involving individuals with ataxia have shown improvements in vestibulo-ocular reflex (VOR) physiology with VPT.

Presented here is a unique case of an individual genetically diagnosed with CANVAS with bilateral vestibulopathy who performed comprehensive VPT interventions in the clinic and home settings and whose vestibular physiology (i.e., VOR gains), gait speed, balance, and clinical neurological symptoms improved or remained stable over a 2-year period.

CASE DESCRIPTION

History

This 60-year-old active female presented to the multi-disciplinary Ataxia Clinic at a tertiary hospital after having seen multiple providers near her home, a remote area with limited access to specialized neurological care. She reported she first noticed balance difficulties in 2014 when experiencing unusual retropulsion when entering a dive tank. She previously enjoyed paddle boarding, but due to progressive imbalance, she had transitioned to kayaking. In 2018, she developed feelings of disequilibrium that worsened with head turns and was associated with blurred vision consistent with "walking" oscillopsia. She also reported imbalance when performing yoga/Pilates and difficulty typing. She ambulated unassisted, yet occasionally "furniture walked". She reported a 25-year history of unexplained chronic cough and difficulty with swallowing as well as heat intolerance, postural lightheadedness, restless legs at night, and occasional urge incontinence. She also experienced insomnia and reported sleeping an average of four hours per night despite sleep hygiene strategies and pharmacological management. She reported no hearing loss. She retired from working full time as a pharmaceutical representative because her symptoms negatively impacting overall ability to function in a work environment. Per her report, her local providers presumed her imbalance was due to anxiety or neuropathy related to previous chemotherapy treatment in 2007. She was referred to the multi-disciplinary Ataxia Clinic by her neurologist. Notably, she had a family history of neurodegenerative conditions. Her mother was diagnosed with Parkinson's disease, her uncle had an undiagnosed gait disorder (onset ~age 70s), and her maternal uncle and aunt had late-onset undiagnosed progressive gait and balance impairments.

Examination

During the oculomotor exam, the patient presented with stable gaze in primary position (i.e., no evidence of spontaneous nystagmus with or without visual fixation). Direction changing gaze-evoked nystagmus was present (right beating with right gaze, left beating with left gaze - with and without visual fixation). Smooth pursuits were saccadic. She had hypometric saccades with down gaze, but otherwise saccades were normal. The visual enhanced vestibulo-ocular reflex (VVOR) with slow head movement was hypometric and the vestibulo-ocular reflex (VOR) with rapid head movement (head impulse test) was impaired bilaterally. VOR suppression was normal. The patient's oculomotor signs were consistent with a cerebellar or central localization. (20)

The patient performed the Scale for Assessment and Rating of Ataxia (21) (SARA), an 8-item clinical scale used to measure the ataxia severity. The test is scored from 0 (no symptoms) to 40 (unable to complete each item). The patient's SARA score was 7.5. See Table 1.

The patient had evidence of dysarthria and dysmetria, as well as impairments of static balance and dynamic balance/gait. Her sensory exam showed absent sensation to light touch and absent proprioception of the bilateral metatarsophalangeal joints. The patient's reflexes were 3+ bilateral patellar and 0 bilateral Achilles. Standing balance was tested using the Modified Clinical Test of Sensory Interaction in Balance and was abnormal: standing, eyes open = 30 seconds; standing, eyes closed = 30 seconds; standing on foam, eyes open = 30 seconds; standing on foam eyes closed = 0 seconds. The patient's strength was within normal limits, and she

Table 1: Item scores for the Scale for Assessment and Rating of Ataxia (21)

Item	Item scoring description	Item score
Gait	[2] Clearly abnormal, tandem walking >10 steps not possible	2
Stance	[2] Able to stand with feet together for > 10 s, but only with sway	2
Sitting	[0] Normal, no difficulties sitting >10 sec	0
Speech	[1] Suggestion of speech disturbance	1
Finger chase	RIGHT [1] Dysmetria, under/ overshooting target <5 cm, LEFT [2] Dysmetria, under/ overshooting target <15 cm	1.5
Finger to nose	RIGHT [0] No tremor LEFT [1] Tremor with an amplitude < 2 cm	0.5
Rapid alternating movements	RIGHT [1] Slightly irregular (performs <10s) LEFT [0] Normal, no irregularities (performs <10s)	0.5
Heel to shin	RIGHT Normal LEFT Normal	0
Total		7.5

exhibited normal tone. She did not display a tremor and showed no evidence of rigidity, dyskinesia, or dystonia.

The patient had no apparent cognitive deficits upon screening but reported difficulties with memory and generalized fatigue.

Outcome Measures

The patient performed the 10-meter walk test (10MWT), Timed Up and Go (TUG), TUG with a cognitive dual task, and Functional Gait Assessment (FGA) without an assistive device. Dynamic visual acuity (DVA) testing was attempted but the patient's inability to consistently coordinate active sinusoidal yaw head rotational movements while maintaining stable gaze fixation may have contributed to inconsistent and perhaps invalid results. The patient completed the Oscillopsia Functional Index (OFI) at baseline and at the one and two-year follow-up. The patient completed the Niigata Persistent Postural-perceptual Dizziness Questionnaire (NPQ) and Dizziness Handicap Inventory (DHI) at the one and two-year follow-up periods. The results of the performance-based and patient-reported outcome measures at baseline, 1, and 2 years are summarized in Tables 2 and 3. Physiologic testing showed baseline VOR gains via video head impulse testing (VHIT) in the yaw plane that were impaired bilaterally with presence of covert and overt compensatory saccades. Vertical canal VOR gain results were inconsistent due to the presence of gaze-evoked nystagmus in the lateral head rotation standardized testing position and hence not reported here. See Figure 1.

A diagnosis of CANVAS was confirmed by the following formal tests: MRI demonstrating cerebellar atrophy of the superior sulcus and midline; electromyography testing that showed evidence of a sensory neuronopathy (ganglionopathy); VHIT revealing evidence of bilateral vestibulopathy, and genetic testing that demonstrated abnormal/biallelic repeat expansion in the replication factor C subunit 1 (RFC-1) gene consistent with CANVAS.

Table 2: Performance-based outcome measures scores

	FGA	TUG (seconds)	TUG-cog (seconds)	10MWT (meters/second)	SARA
Baseline	11	8.7	10.5	0.87	7.5
1-year	15	10.5	12.8	1.12	6.5
2-years	18	9.6	11.6	1.17	6.5
Normal range	>27/30	<8.39	<9.82	1.24-1.34	<0.4
Fall risk score	<22/30	≥13.5	>15	<1.0	

Abbreviations: 10MWT, 10-meter walk test; FGA, Functional Gait assessment; SARA, Scale for Assessment and Rating of Ataxia; TUG, Timed up and Go; TUG-cog, TUG with cognitive dual task

Table 3: Patient-reported outcome measure scores

	NPQ	OFI	DHI	ABC (%)
Baseline	NA	27	NA	NA
1-year	8	35	24	72.5
2-years	13	21	22	73.13
Normal range	0	<12	0	≥80
Fall risk cut-off score				<80

Abbreviations: ABC, Activities-specific Balance Confidence Scale; DHI, Dizziness Handicap Inventory; NA, not performed; NPQ, Niigata Persistent Postural-perceptual Dizziness Questionnaire; OFI, Oscillopsia Functional Index

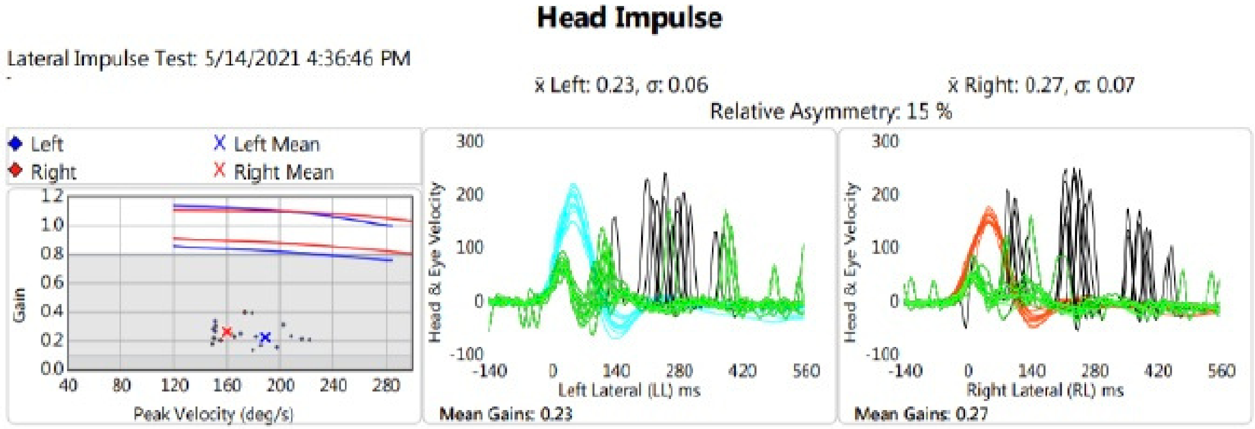


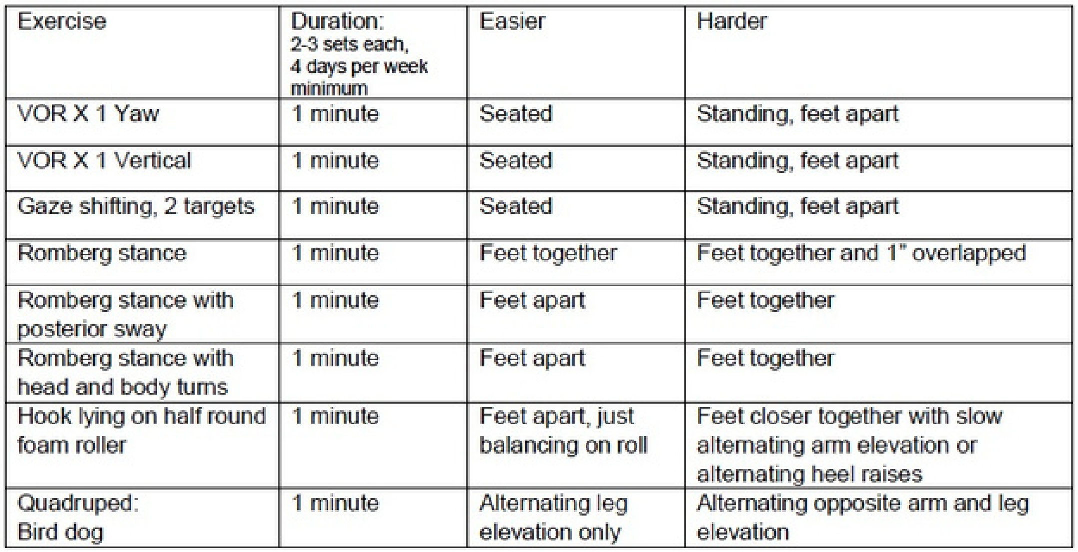
Figure 1: Baseline video head impulse testing with passive head rotations revealed abnormal VOR responses with presence of covert and overt compensatory saccades in the yaw plane bilaterally. Head rotation velocity left (blue), right (red), compensatory saccade (black).

Interventions

The patient's neurologist prescribed the following medications: Alprazolam (Xanax) 0.25mg tablet prn, melatonin (5mg as needed), pregabalin (Lyrica) 150mg nightly, and trazodone (2x100mg nightly).

Rehabilitation was targeted to improve gaze stability with head movement via VOR X1 viewing exercises with guidance to move the head sinusoidally as fast as possible as long as the target remained clear and gaze shifting exercises between 2 targets. Balance exercises in standing were prescribed with suggested variations based on her ability and self-reported intensity of the exercise challenge. On a 0-10 scale (0 =easy, 10=challenging to the point of falling), she was encouraged to challenge herself at a level 7/10, or somewhat difficult intensity.(14) Emphasis was on safety and performing the balance exercises slowly and with controlled movements. She demonstrated competency in performing the exercises in the clinic prior to continuing the exercises at home. The patient was encouraged to perform the gaze stability tasks daily in combination with the balance tasks at a minimum of 20 minutes per day, 4 days per week at a self-perceived intensity level of 7/10 challenge for all tasks.(14) Gait tasks with head and body turns were initially deferred due to her inability to perform them without risk of falling. She later progressed to incorporating ambulation with head and body turns near a wall or with a family member close for safety. The physical therapist also provided core strengthening exercises incorporating balance/coordination challenges to promote stamina for the standing gaze and balance tasks. Exercises included tasks in quadruped and hook lying positions on a half-round foam roller close to the ground for

Table 4. Examples of home and in-clinic gaze stability and balance exercises with gradients of challenge



Exercise	Duration: 2-3 sets each, 4 days per week minimum	Easier	Harder
VOR X 1 Yaw	1 minute	Seated	Standing, feet apart
VOR X 1 Vertical	1 minute	Seated	Standing, feet apart
Gaze shifting, 2 targets	1 minute	Seated	Standing, feet apart
Romberg stance	1 minute	Feet together	Feet together and 1" overlapped
Romberg stance with posterior sway	1 minute	Feet apart	Feet together
Romberg stance with head and body turns	1 minute	Feet apart	Feet together
Hook lying on half round foam roller	1 minute	Feet apart, just balancing on roll	Feet closer together with slow alternating arm elevation or alternating heel raises
Quadruped: Bird dog	1 minute	Alternating leg elevation only	Alternating opposite arm and leg elevation

safety. Table 4 provides examples of gaze stability and balance exercises with suggested “easier” or “harder” variations. Finally, the patient was encouraged to perform aerobic exercise such as recumbent stationary biking at her local gym at a frequency of 5 times per week for 30 minutes at a suggested target heart rate of 103 beats per minute with graded increase to 127 beats per minute, or 65%-80% of her adjusted maximum heart rate.

The patient lived in an area where there were no local neurological rehabilitation services, and telehealth was not an option due to licensure restrictions. Guidelines for how to self-assess exercise intensity and safety were discussed. For example, the patient practiced standing exercises close to a corner as she “explored” how to maintain her balance with a self-perceived 7/10 intensity. Fortunately, this individual was physically active, and self-efficacy for management of her chronic health condition came relatively naturally to her. She reported completing the exercises at a frequency and intensity exceeding the minimum recommended dosage. She was highly motivated and compliant with her home program.

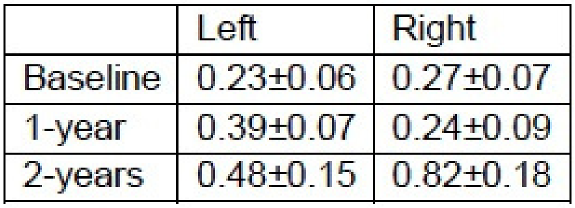
Outcomes

Over a 2-year time period of VPT, the patient’s SARA score improved and remained stable. Her gait velocity improved by 0.3m/s, and dynamic gait and balance, as measured using the FGA, improved by 6 points, exceeding the minimal clinically important differences (0.9 m/s and four points, respectively). The FGA score indicated she was at risk for falls at baseline and the one- and two-year follow-ups. See Table 2.

The patient’s ABC score predicted she was at risk for falls. Over a 2-year period of VPT, her perceived level of oscillopsia slightly improved, perceived dizziness and balance confidence remained relatively unchanged, and perceived motion sensitivity slightly worsened.

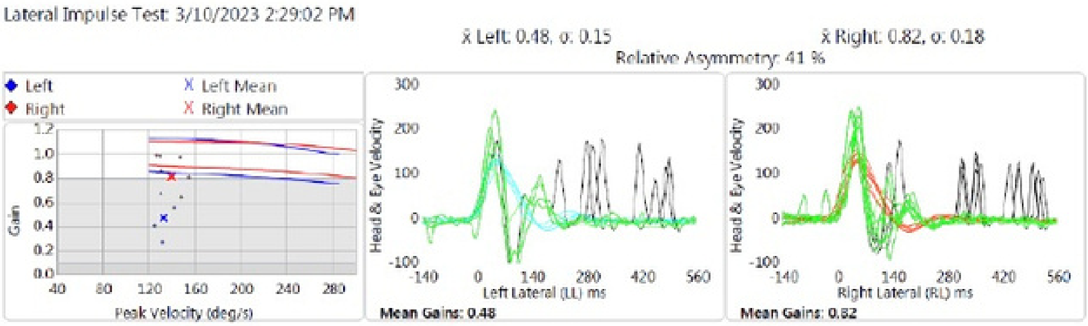
The patient’s VOR gains were severely impaired bilaterally, which was consistent with her clinical head impulse test result. After a 2-year period of VPT, her VOR responses to passive head rotation significantly improved bilaterally. See Table 5 and Figure 2.

Table 5. Results of video head impulse test performed in the yaw plane (vestibular ocular reflex gains, mean/standard deviation)



	Left	Right
Baseline	0.23±0.06	0.27±0.07
1-year	0.39±0.07	0.24±0.09
2-years	0.48±0.15	0.82±0.18

Video Head Impulse Test at 1 year



Video Head Impulse Test at 2 years

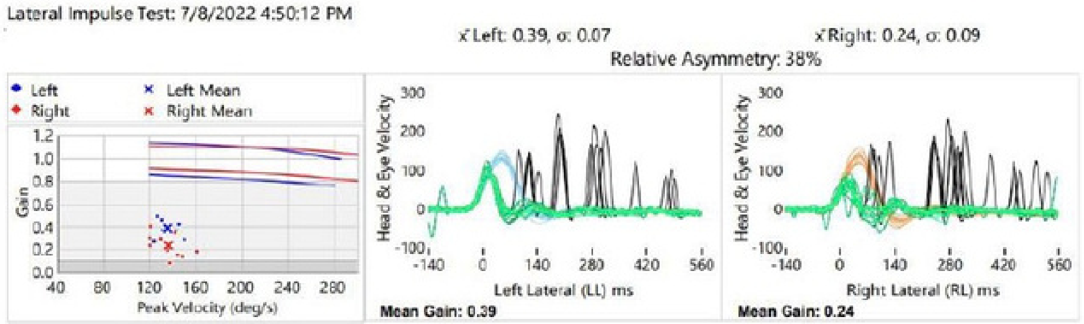


Figure 2: Yaw plane video head impulse test results at 1 and 2 years. After a 2-year period of vestibular physical therapy, the patient's vestibule-ocular reflex responses to passive head rotation were still below normal for her age, but significantly improved bilaterally.

Discussion

This case highlights the novel effects of intensive VPT on improving vestibular physiology (i.e., VOR gains) and function in an individual with CANVAS, an ataxia considered to have a poor prognosis given the presence of diffuse neuronopathy. More than 50 hereditary ataxias and their pathophysiology and symptomatology have been identified since the first genetic mutation for spinocerebellar ataxia, type 1 was discovered in 1993.(22) In 2004, Cerebellar Ataxia with Neuropathy and bilateral Vestibular Areflexia Syndrome (CANVAS) phenotype was first described (23) as a late-onset ataxia with slow progressive cerebellar dysfunction, bilateral vestibulopathy, as well as a diffuse sensory deficit (later identified as a ganglionopathy or neuronopathy).(24,27) The vestibular dysfunction mechanism in CANVAS is considered part of the diffuse sensory impairment. Specifically, a Scarpa's ganglionopathy putatively impairs vestibular function of all six semicircular canals and utricle, with spared saccule and cochlear function.(24,25)

In 2019, the gene for CANVAS, replication factor C subunit 1 (RFC-1), was identified as well as a genetic test to identify RFC-1 presence.(26) Among those with previously undiagnosed ataxias, 3.2% have eventually been diagnosed with CANVAS, either as a recessive RFC-1 genetic variant (1 of every 1.4 tested), or a new mutation (de novo).(27) Interestingly, since the identification of the CANVAS genetic variant, isolated neuronopathy, without the presence of vestibulopathy, is now considered a possible CANVAS phenotype.

This individual presented to our multi-disciplinary Ataxia Center with an undiagnosed ataxia. Key findings included her history of chronic cough (bulbar involvement), gradual late onset of imbalance, oscillopsia, central ocular motor signs, incoordination, dysautonomia, family history, cerebellar atrophy on imaging, as well as long fiber sensory neuronopathy, and bilateral vestibulopathy. Formal testing of otolith function was not performed in this case. Yet, of interest, her hearing was spared despite putative diffuse sensory neuropathy/bulbar involvement, consistent with the literature.(28)

Video head impulse testing identified the presence of bilateral vestibulopathy. Yet, the patient's perceived symptoms and the severity of vestibular physiology impairment did not correlate, which is consistent with the findings of a retrospective study in ataxia.(9) Others have also shown that central oculomotor, axial, and appendicular neurological impairments do not always correlate in ataxia.(29)

Genetic testing confirmed a diagnosis of CANVAS (RFC-1 recessive variant). Evidence in the literature indicates that individuals with neurodegenerative cerebellar ataxias have potential to improve with combined intensive balance and endurance training.(10–13,15,16) Exercise dosage was recommended in this case based on previous exercise studies in individuals with degenerative cerebellar ataxia.(11,30,31) One study showed intensive coordination training at a frequency of 7 days per week for 1 hour per day at the clinic and home yielded positive results in gait velocity, kinematics, and clinical measures of dynamic balance.(11) In their cohort, those with cerebellar ataxia improved more than individuals with sensory ataxia. Another study of individuals with cerebellar degenerative disease demonstrated that self-reported intensity of challenge when performing home balance exercises was more important than exercise frequency. A minimum of 20 minutes, 4 times per week of balance exercises, with a self-perceived level of difficulty of 7/10 for each task was enough to significantly improve gait speed.(14) Recently, a randomized control trial involving individuals with cerebellar degenerative disease and ataxia showed home aerobic training via stationary biking 5 days per week for 30 minutes at a level of 60-85% of adjusted heart rate maximum was more effective than balance training for improving clinical neurological scores.(31,32)

In this case, gait velocity, dynamic balance, and fall risk improved to a level of clinical significance consistent with what has been demonstrated in previous rehabilitation studies of individuals with cerebellar degenerative disease.(2,14,19) The novel improvements in VOR gains with passive head rotation demonstrated in this patient provides evidence that vestibular physiological motor learning is possible among individuals with CANVAS with intensive VPT.

Why were such improvements observed? Studies have shown adaptation, or error-based motor learning, is impaired in cerebellar dysfunction.(33) Other studies have shown reinforcement feedback motor learning is possible in cerebellar degenerative ataxias with the help of repetition and motor exploration, putatively by upweighting brainstem and basal ganglia functions.(34) VOR improvements may be attributed to reinforcement of feed-forward movements through intense practice, thus decreasing variability and improving gaze accuracy overtime.(35)

Gaze and postural stability training in combination with home aerobic exercise at high intensity and frequency with guidance for self-assessment and suggested self-modifications of the tasks (i.e., easier or harder) to consistently set a difficult self-challenge were important components to drive positive change in this patient. This unique case demonstrates novel improvement of VOR physiology with intensive gaze and postural stabilization training, in addition to aerobic exercise. Individuals with CANVAS have a poorer prognosis, yet this case demonstrates that intensive VPT can drive improvement across several domains. The results of intensive training in this individual living with a chronic cerebellar degenerative health condition illustrates the value VPT and self-efficacy for long term management.

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JOIN US FOR

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VESTIBULAR REHABILITATION
SPECIAL INTEREST GROUP

We would love for you to join us at CSM for a social event to mingle with other vestibular therapists!

Thursday, February 13th
6:30–9:00
Flyer Saucer Draught Emporium
705 Main St., Houston, TX 77002

The gathering will take place on the 2nd floor/loft area.
Separate checks are available for food/drink.
*Individuals are responsible for their own food/drink bill.

CSM 2025 Preview

Victoria Gaugis, PT, DPT*
VA Outpatient Clinic, Terre Haute, IN

The 2025 Combined Section Meeting (CSM) will take place at the George R. Brown Convention Center in Houston, Texas, from February 13-15. This year's lineup of presenters promises to offer valuable insights and showcase the latest advancements in physical therapy. For updates and exciting event details, visit the APTA website. Below is the current list of confirmed speakers:

Thursday 11AM-1PM
Universal Canalith Repositioning Maneuver for BPPV Clears All Three Ipsilateral Canals: Development and Implementation
Presented By: Janet Odry Helminski, PT, PhD, Richard Rabbitt and Christopher M. Smith

Concussion Discussion in Performing Arts: A Multi-Faceted Approach to Assess, Treat, and Advocate for Performers
Presented By: Kristen Hope Schuyten, PT, DPT, MS, Cindy Enderle Munday, PT, MPT, Allyssa Memmini, PhD, LAT, ATC and Phillip N. Schuyten, PT, DPT

Thursday 3 PM-5 PM
Critical Conversations and Practical Management Strategies for Patients with Persistent Postural Perceptual Dizziness (PPPD)
Presented By: Rachel D. Wellons, PT, DPT and Sara Gaudet MacDowell, PT

Integrating Neurologic, Orthopedic, and Sport Approaches in Concussion: A Multidisciplinary & Multispecialty Perspective
Presented By: Alexander Paul Peters, PT, DPT, ATC, Jacob I. McPherson, PT, DPT, PhD and Haley M. Chizuk

Friday, 3-5 PM
Dynamic Exercise after Sport-Related Concussion: Timing, Testing, and Treatment
Presented By: Kayla M. Covert, PT, DPT, Sarah Elizabeth Ostop, PT, Victoria L. Kochick, PT, DPT and Erin Isanhart, PT, DPT

Identification and Management of Persistent Vestibular-Oculomotor and Cervical Symptoms after Concussion.
Presented By: Jennifer Lynn Fay, PT, Eric Scott Ross, PT and Margaret Waskiewicz

Saturday 8-10 AM
Moving Towards Precision Rehabilitation: Part 2 Applying Clinical Phenotyping in Vestibular Physical Therapy
Presented By: Colin R. Grove, PT, DPT, MS, PhD, Eric R. Anson, PT, PhD, Janene M. Holmberg, PT, DPT, Susan L. Whitney, PT, DPT, ATC, FAPTA and Laura Olsen Morris, PT

Poster Presentations

THURSDAY:
Vestibular Evaluation and Treatment of Vogt Koyanagi Harada Syndrome
Syeda Sarosh Ahmed, PT, DPT

Concurrent Headshake and Postural Training Using Virtual Reality Improves Motor Learning and Retention
Kwadwo Osei Appiah-Kubi, PT, MSPT, PhD, Emmanuel Asante-Asamani, BS, MS, PhD, Jenay Bartlett, Rawan Almadani DPT, Camille Devereaux, PT, DPT, Amber K. Jones, SPT, Ariana Rae Kelly, SPT, Shea Frady, PT, DPT and Emmanuel Bonney PT, MS, PhD

Computerized Torsional Assessment of Nystagmus
Amy Ruth Cassidy, PT, Susan L. Whitney, PT, DPT, ATC, FAPTA, Michelle Petrak, Ph.D., CCC-A and Kamrin Barin

Transcranial Magnetic Stimulation Use with Chronic Vestibular Disorders: A Scoping Review
Elizabeth Danielle Cornforth, PT, Devashish Tiwari, PT, DPT, PhD, Teresa Jacobson Kimberley, PT, PhD, FAPTA, Emily Delepine, SPT, Stephane Lin, SPT, Jacquelyn Burke, PT, Brandon Peterson, SPT and Rachel M. Hickey, SPT

Persistent Vertigo and Ageotropic Nystagmus Post Cochlear Implant
Mary M. Crumley, PT, DPT

Pearls on ROSE – Rehabilitation Oculomotor Screening Evaluation
Elizabeth Dannenbaum, Tina Yu-Zhou Li, Alessia Vitullo, Sophia Ergina and Joyce Fung

Can Gaze Evaluation Inform the Rehabilitation of Persistent Postural-Perceptual Dizziness?
Elizabeth Dannenbaum, Yunyi Liu, Kairy Dahlia, Marc-Alexandre Wagnac, Anouk Lamontagne and Joyce Fung

Putting a Positive Spin on It: OPTIMAL Theory Application to Improve the Dizziness Experience
Tobin Dubuc, PT, DPT, Marc Allen Broberg, PT, DPT and Rebecca Lewthwaite, PhD

Identification and Treatment of Decompensated Vestibular Hypofunction in an Older Adult
Derek Joseph Fanto, PT, DPT

Functional Vision Head Impulse Test: A Functional Measure of the Vestibulo-Ocular Reflex
Courtney Goetz, Elizabeth Fuemmeler, Michelle Petrak and Linda Joan D'Silva, PT, PhD

Gait Characteristics of Individuals with Visual Vertigo and Healthy Controls While Walking with Head Movements
Karen Louise Schaubert Goodman, PT, DPT, Hannah McDermott, PT, DPT and Keith Robert Cole, PT, DPT, PhD

Navigation Ability Is Associated with the Functional Use of Visual and Vestibular Inputs for Balance
Colin R. Grove, PT, DPT, MS, PhD, Keenan Batts, Bryan C. Heiderscheit, PT, PhD, FAPTA and Susan L. Whitney, PT, DPT, ATC, FAPTA

Identifying Benign Paroxysmal Positional Vertigo in a Patient Post Stroke: A Case Study
Marissa Ruke Conrad, PT, MSPT, Goldshawn Guinto, PT, DPT and Marla Laloo, PT, DPT

Improvement in Saccadometry Performance in People with Concussion after Physical Therapy Intervention
Evin Hill, SPT, Shellie Zsoldos, PT, DPT and Chia-Cheng Lin, PT, MSPT, PhD

A Lifetime of Dizziness: Management of Central Vestibular Dysfunction in an Individual with Cerebal Palsy
Zachary Knox, PT, DPT

Multisensory Impairments Influence Spatial Navigation Skills in Community-Dwelling Older Adults
Taryn Jones, SPT, Courtney Goetz, Hinrich Staecker and Linda Joan D'Silva, PT, PhD

Implementation of a Vestibular Program Framework in a Hospital-Based Health Care System
Stacey Marie Lane, PT, DPT, Jaclyn Michelle Gould, PT, DPT, Leslie Ann Hefner, PT, DPT, Holly Joelle Paczan, PT, Liza Meinkins, PT, DPT, Hannah Redd, PT, DPT, Carolyn Jean Sykes, PT, DPT and Meaghan Rubsam, PT, DPT

Agreement Among Expert Physical Therapist Clinicians in Naming Nystagmus: A Qualitative Study Design.
Lori Ann Leineke, PT, DPT, EdD, Alessandra Garcia Trepte and Bridget Ripa Eubanks, PT, DPT

Benign Paroxysmal Positional Vertigo, Urgency Urinary Incontinence, and Falls: Is Vitamin D the Missing Link?
Matthew Todd Martin, PT, DPT and Amanda Thompson Mahoney, PT, DPT

Sinister or Benign? Assessing Dizziness in the Emergency Room
Christopher Martinez, PT, DPT, Alec Christian Davis, PT, DPT, Rachael Suzanne Arabian, PT, DPT and Linda Papa, MD

Optimizing Vestibular Rehabilitation through Integration of the Rehabilomics Framework
Ignacio Novoa Cornejo, MS, Vijaya Prakash KRISHNAN Krishnan Muthaiah, PT, PhD and Susan L. Whitney, PT, DPT, ATC, FAPTA

Application of Dai Optokinetic Treatment of Mal De Debarquement in an Outpatient Clinical Setting
Kimberly Anne Phelps, PT, DPT

Management of Dizziness in an Adult with Infantile Nystagmus: Does Visual Fixation Matter?
Christina Nicole Romeo, PT, DPT

Effect of Vestibular Rehabilitation Exercise Dose on Vestibular-Related Outcome Measures: A T-REV Randomized Controlled Trial
Patrick Joseph Sparto, PT, PhD, FAPTA, Anne Mucha, PT, DPT, MS, Susan L. Whitney, PT, DPT, ATC, FAPTA, Michael Collins, Charity Galena Patterson, Clair Smith, Courtney Perry, Joseph M Furman, MD, PhD, Selena Ann Bobula, PT, DPT, Jamie N. Hershaw, PhD, Christy Mote, Steven Wilcox, Alan Peterson, Stacy Young-McCaughan, Scot Engel, PsyD, Sean Tim Suttles, PT, DPT and Anthony Kontos

Validation of a Smartphone-Based Application Using Accelerometers to Assess Postural Stability and Head Velocity
Stacia Hall Thompson, PT, DPT, PhD, Kade McFall, PT, DPT, Amanda Ransom, PhD, Brittany Matsinger, PT, DPT, Christopher Mygrant, PT, DPT, EMT-B, MS and Lauren N. Bishop, SPT

Emergency Department Physical Therapists Cover Vestibular Treatment and Generate Streamlined Outpatient PT Referral
Cole Uebelhor, PT, DPT and Matthew Schultz

Quantifying Vestibular Precision in the Lab and Clinic
Andrew Raymond Wagner, PT, DPT

Stochastic Earth Vertical Translations Increase Sway Velocity during Upright Stance.
Andrew Raymond Wagner, PT, DPT and Daniel M Merfeld

Cervical Spine Range of Motion, Pain, and Disability in Individuals with Vestibular Dysfunction
Rachel D. Wellons, PT, DPT, Sydney Evans Duhe, PT, DPT, Sara Gaudet MacDowell, PT, Chloe Struble, PT and Therese M. Schiro, PT, DPT

Vestibular Experiences in Clinical Education: What Are Students Seeing in the Clinic?
Heather Witt, PT, Viviana Ortiz Guerrero, SPT, Karsen Lynn Hunter, SPT, Emily Tweel, SPT, Evonie Daugherty and Nathan Johnson

The Effect of Music Use on Vestibular Central Pathologies: A Case Report
Madison Nicole Yates, PT, DPT

FRIDAY:

Vestibular Implications of Trigeminal Neuralgia Microvascular Decompression
Rachael Suzanne Arabian, PT, DPT

Vestibular Rehabilitation Experiences in Physical Therapy Clinical Education: A Scoping Review
Heather Witt, PT, Paiten Bush, SPT and Madison Bennett, SPT

Vestibular Function in Parkinson Disease Compared to Healthy Adults and the Effects of Dopaminergic Medication
Jennifer Lynn Brodsky, DPT, James O. Phillips, Andrew Humbert, Sujata Pradhan, PT, PhD, Molly Gries and Valerie Kelly, PT, PhD

SATURDAY:

Management of Balance and Strength Deficits in Elderly Male with Multiple Sclerosis and Vestibular Hypofunction
John Anthony Wray Cantu, PT, DPT

The Effect of Vestibular Rehabilitation on Balance for Children with Hearing Loss: A Systematic Review
Alyssa Bradford, PT

Implementation of Routine Vestibular Screening for Pediatric Patients with Cystic Fibrosis and Primary Ciliary Dyskinesia
Elizabeth Nutter, PT, DPT and Nashwa Khalil, PT, DPT

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Topics in Vestibular Physical Therapy (TVPT) is the official publication/newsletter of the Vestibular Rehabilitation Special Interest Group (VRSIG) of the Academy of Neurologic Physical Therapy (ANPT).
The purpose of the publication is to disseminate clinically relevant information to our members who treat individuals who have vestibular related symptoms.

The editors of the TVPT will accept literature reviews, brief research reports, clinical perspectives, conference presentation summaries, and clinical case studies. Editors will support and mentor clinicians who wish to contribute clinical experience and knowledge in this forum. The editors invite members to suggest topics and guest editors with expertise in a targeted topic.

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