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January Topic: Central Vestibular Dysfunction

January 6, 2021
Zhe, X., Gao, J., Chen, L., Zhang, D., Tang, M., Yan, X., . . . Zhang, X. (2020**). Altered structure of the vestibular cortex in patients with vestibular migraine.** Brain and Behavior, 10(4) doi:http://dx.doi.org.augie.idm.oclc.org/10.1002/brb3.1572

Introduction: Previous voxel-based morphometry (VBM) studies have revealed changes in brain structure in patients with vestibular migraine (VM); these findings have improved the present understanding of pathophysiology. Few other studies have assessed the association between structural changes and the severity of dizziness in VM. This study aimed to examine the structural changes and cortical morphometric features associated with migraine and vertigo attacks in patients with VM.
Methods: Twenty patients with VM and 20 healthy normal volunteers were scanned on a 3-tesla MRI scanner. The gray matter volume (GMV) was estimated using the automated Computational Anatomy Toolbox (CAT12). The relationship between clinical parameters and morphometric abnormalities was also analyzed in VM.
Results: Compared with controls, VM patients have decreased GMV in the prefrontal cortex (PFC), posterior insula–operculum regions, inferior parietal gyrus, and supramarginal gyrus. Moreover, patient scores on the Dizziness Handicap Inventory (DHI) score showed a negative correlation with GMV in the posterior insula–operculum regions.
Conclusion: These findings demonstrated abnormality in the central vestibular cortex and correlations between dizziness severity and GMV in core regions of the vestibular cortex of VM patients, suggesting a pathophysiological role of these core vestibular regions in VM patients.
PMID: 32157823
Link to free text: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7177586/

January 14, 2021
Lee, J-O, Lee, E-S, Kim, J-S, et al. **Altered brain function in persistent postural perceptual dizziness: A study on resting state functional connectivity.** Hum Brain Mapp. 2018; 39: 3340– 3353

This study used resting state functional magnetic resonance imaging (rsfMRI) to investigate whole brain networks in patients with persistent postural perceptual dizziness (PPPD). We compared rsfMRI data from 38 patients with PPPD and 38 healthy controls using whole brain and region of interest analyses. We examined correlations among connectivity and clinical variables and tested the ability of a machine learning algorithm to classify subjects using rsfMRI results. Patients with PPPD showed: (a) increased connectivity of subcallosal cortex with left superior lateral occipital cortex and left middle frontal gyrus, (b) decreased connectivity of left hippocampus with bilateral central opercular cortices, left posterior opercular cortex, right insular cortex and cerebellum, and (c) decreased connectivity between right

nucleus accumbens and anterior left temporal fusiform cortex. After controlling for anxiety and depression as covariates, patients with PPPD still showed decreased connectivity between left hippocampus and right inferior frontal gyrus, bilateral temporal lobes, bilateral insular cortices, bilateral central opercular cortex, left parietal opercular cortex, bilateral occipital lobes and cerebellum (bilateral lobules VI and V, and left I–IV). Dizziness handicap, anxiety, and depression correlated with connectivity in clinically meaningful brain regions. The machine learning algorithm correctly classified patients and controls with a sensitivity of 78.4%, specificity of 76.9%, and area under the curve = 0.88 using 11 connectivity parameters. Patients with PPPD showed reduced connectivity among the areas involved in multisensory vestibular processing and spatial cognition, but increased connectivity in networks linking visual and emotional processing. Connectivity patterns may become an imaging biomarker of PPPD.
PMID: 29656497
Link to free text: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6866559/

January 20, 2021
Katz-Nave, G., Adini, Y., Hetzroni, O.E. and Bonneh, Y.S. **Sequence Learning in Minimally Verbal Children With ASD and the Beneficial Effect of Vestibular Stimulation**. Autism Research, (2020)13: 320-337

People with autism spectrum disorder (ASD) and especially the minimally verbal, often fail to learn basic perceptual and motor skills. This deficit has been demonstrated in several studies, but the findings could have been due to the nonoptimal adaptation of the paradigms. In the current study, we sought to characterize the skill learning deficit in young minimally verbal children with ASD and explore ways for improvement. For this purpose, we used vestibular stimulation (VS) whose beneficial effects have been demonstrated in the typical population, but the data regarding ASD are limited. We trained 36 children ages 6–13 years, ASD (N = 18, 15 of them minimally verbal) and typical development (TD, N = 18), on a touch version of the visual-motor Serial-Reaction-Time sequence-learning task, in 10 short (few minutes) weekly practice sessions. A subgroup of children received VS prior to each training block. All the participants but two ASD children showed gradual median reaction time improvement with significant speed gains across the training period. The ASD children were overall slower (by ~250 msec). Importantly, those who received VS (n = 10) showed speed gains comparable to TD, which were larger (by ~100%) than the ASD controls, and partially sequence-specific. VS had no effect on the TD group. These results suggest that VS has a positive effect on learning in minimally verbal ASD children, which may have important therapeutic implications. Furthermore, contrary to some previous findings, minimally verbal children with ASD can acquire, in optimal conditions, procedural skills with few short training sessions, spread over weeks, and with a similar time course as non-ASD controls.
PMID: 31729171

January 28, 2021
Daniel, A, Barker, L, Martini, M. **Pain modulation by illusory body rotation: A new way to disclose the interaction between the vestibular system and pain processing.** Eur J Pain. 2020; 24: 1119– 1129

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Background: Clinical and experimental evidence advocates a structural and functional link between the vestibular and other sensory systems. For instance, visuo-vestibular and vestibular–somatosensory interactions have been widely reported. However, whether visual inputs carrying vestibular information can modulate pain is not yet clear. Recent evidence using natural vestibular stimulation or moving visual stimuli, points at an unspecific effect of distraction.
Methods: By using immersive virtual reality (VR), we created a new way to prompt the vestibular system through the vision of static visual cues, studying the possible interaction with pain. Twenty-four healthy participants were visually immersed in a virtual room which could appear with five different degrees of rotation in the sagittal axis, either towards the right, left or with no rotation. Participants' heat pain thresholds and subjective reports of perceived body rotation, sense of presence and attention were measured.
Results: 'Being' in a tilted room induced the sensation of body rotation in our participants, even though they were always in an upright position. We also found that rotating the visual scenario can modulate the participants' pain thresholds, determining a significant increase when a left tilt is displayed. In addition, a positive correlation between the perceived body midline rotation and pain threshold was found when the virtual room was titled 15 degrees toward the left. Importantly, all VR conditions were found to be equally distractive.
Conclusions: Vestibular information present in static visual cues can modulate experimentally-induced acute pain according to a side-dependent manner and bypassing supramodal attentional mechanisms. These findings may help refining pain management approaches based on multimodal stimulation.
Significance: This study explored how the visualization of static environments in immersive virtual reality can lead to pain threshold modulation through the activation of the vestibular system. Immersion into rotated virtual environments led to the illusory sensation of body rotation, and this sensation was found to be related with a modulation of pain perception. Possible analgesic effects due to distraction could be ruled out. These results expand our current knowledge about how the visual, vestibular and somatosensory (pain) systems interact. These findings may influence future pain treatment strategies based on multisensory stimulation.
PMID: 32170809

February Topic: COVID and Dizziness

February 4, 2021
Malayala SV, Raza A. **A Case of COVID-19-Induced Vestibular Neuritis.** Cureus. 2020;12(6):e8918. Published 2020 Jun 30. doi:10.7759/cureus.8918

The World Health Organization (WHO) declared COVID-19, a novel coronavirus infection, as a pandemic in March 2020. Since the origin of the disease in Wuhan, China, understanding the pathophysiology, clinical presentation, screening guidelines, and management of the disease has been ever-evolving.

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Though respiratory pathologies have been the major complications of a COVID-19 infection, other presentations like abdominal pain, deep venous thrombosis, cardiomyopathy, and even acute cerebrovascular ischemic attacks have been reported. We present a case of a young patient presenting with vertigo, possibly from COVID-19-induced acute vestibular neuritis. This is a 20-year-old Hispanic female patient presenting with intractable vertigo, nausea, and vomiting but without any typical symptoms like fever, cough, or shortness of breath. Initial examination and imaging ruled out an acute stroke. There was minimal improvement in her vestibular symptoms with the recommended COVID-19 treatment as of March 2020 (hydroxychloroquine and azithromycin) and symptomatic management. Her inflammatory markers were surprisingly normal all through the hospital course. She was then treated with oral prednisone and subsequently discharged home after a prolonged course of eight days. The pathophysiology of COVID-19-induced vestibular neuritis could be similar to any other viral infection. Clinicians should consider COVID-19 in the differential diagnosis for patients presenting with similar symptoms, especially in areas of a high prevalence of this disease. Early diagnosis of COVID-19 in such cases is important for proper isolation, to minimize exposure and avoid further unnecessary investigations. These symptoms will just resolve with symptomatic management like any other case of vestibular neuritis without any further management that is specific for a COVID-19 infection.
PMID: 32760619
Link to free article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7392187/

February 11, 2021
Saniasiaya J, Kulasegarah J. **Dizziness and COVID-19.** Ear Nose Throat J. 2021;100(1):29-30. doi:10.1177/0145561320959573

Coronavirus 2019 or COVID-19 is a novel entity which had led to many challenges among physicians due to its rapidly evolving nature. Vertigo or dizziness has recently been described as a clinical manifestation of COVID-19. Countless studies, emerging daily from various parts of the world, have revealed dizziness as one of the main clinical manifestation of COVID-19. This is not surprising as dizziness has historically been associated with viral infections.
An earlier published study from China found dizziness to be the most common neurological manifestation of COVID-19.1 Dizziness was proposed to occur ensuing the neuroinvasive potential of severe acute respiratory syndrome coronavirus 2 or SARS-CoV-2 virus which causes COVID-19. Baig et al postulated that the virus enters the neural tissue from circulation and binds to the angiotensin-converting enzyme 2 receptors found in the capillary endothelium.2 Apart from that, direct invasion, hypoxia, hypercoagulopathy, as well as immune-mediated insult were among the postulated mechanism of neuroinvasion leading to dizziness.3
A literature search was performed using articles published in PubMed on August 1, 2020, to identify dizziness as a clinical manifestation of COVID-19. The keywords used for the article search include giddiness, dizziness, vertigo, COVID-19, SARS CoV 2, Coronavirus disease. To our knowledge, this is the first article that outlines the association between dizziness and COVID-19.

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We obtained 14 articles, which include 3 case reports and 11 studies (Table 1). A total of 141 patients were pooled from this review. All patients included in this review had dizziness/vertigo as a presenting symptom. Dizziness was the initial presentation of COVID-19 in 3/141 patients (2.13%),9,11,13 whereby in 2 of these patients, dizziness was later followed by respiratory symptoms.9,13 Most of the studies reporting on dizziness as a clinical manifestation hails from China (11/14), the epicenter which gave rise to the pandemic. Of the 14 studies included, dizziness was specifically investigated and treated only in 2 studies9,11 as dizziness was not the highlight in most studies, it was not investigated and described thoroughly. Additionally, the outcome of dizziness was mentioned only in 1 study by Malayala et al,11whereby vestibular rehabilitation was carried out for the patient successfully.
Dizziness, albeit a nonspecific COVID-19 symptom, requires thorough investigation notably to determine its leading cause including, acute labyrinthitis, vestibular neuritis, acute otitis media, or secondary to stroke following COVID-19.
We would like to emphasize that dizziness should not be taken lightly as it has been proven to be a notable clinical manifestation among COVID-19 patients. Parallel to that, association with other audiovestibular manifestations such as hearing loss and tinnitus ought to be determined. Persistent dizziness posttreatment from COVID-19 requires referral to the Otorhinolaryngology Department for thorough examination and investigation. Additionally, we recommend vestibular rehabilitation therapy, which has revealed promising results, to be carried out for stable COVID-19 patients with dizziness. Lastly, it is imperative that attending physicians remain vigilant, especially when managing nonspecific symptoms such as dizziness, as it can be easily overlooked.
PMID: 32931322
Link to free article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7492824/

February 18, 2021
Luís ME, Hipólito-Fernandes D, Mota C, Maleita D, Xavier C, Maio T, Cunha JP, Tavares Ferreira J. A **Review of Neuro-Ophthalmological Manifestations of Human Coronavirus Infection.** Eye Brain. 2020 Oct 30;12:129-137. doi: 10.2147/EB.S268828.

Introduction: Human coronavirus (HCoVs) are a group of viruses with recognized neurotropic and neuroinvasive capabilities. The reports on the neurological and ocular findings are increasing day after day and several central and peripheral neurological manifestations are already described. However, none specifically describes the neuro-ophthalmological manifestation of HCoVs. This is the first article specifically reviewing neuro-ophthalmological manifestations of HCoVs infection.
Methods: PubMed and Google Scholar databases were searched using the keywords: coronaviridae, coronavirus, COVID-19, SARS-CoV-2, SARS-CoV-1, MERS, ocular, ophthalmology, ophthalmological, neuro-ophthalmology, neurological, manifestations. A manual search through the reference lists of relevant articles was also performed. There were no restrictions concerning language or study type and publications not yet printed but available online were considered.
Results: Coronavirus eye involvement is not frequent and includes mostly a typical viral follicular conjunctivitis. Recently, retinal anatomical alterations were described using optic coherence

tomography. Neuro-ophthalmological symptoms and signs can appear isolated or associated with neurological syndromes. The manifestations include headache, ocular pain, visual impairment, diplopia, and cranial nerve palsies secondary to Miller Fisher syndrome, Guillain-Barré syndrome, or encephalitis, and nystagmus.
Conclusion: Neurological and neuro-ophthalmological syndromes, symptoms, and signs should not be neglected and a complete ophthalmological examination of these patients should be performed to fully describe ocular manifestations related to HCoVs. We believe that major ocular and neuro-ophthalmological manifestations reports lack due to safety issues concerning detailed ophthalmological examination; on the other hand, in a large number of cases, the presence of life-threatening coronavirus disease hinders ocular examination and ophthalmologist's visit to the intensive care unit
PMID: 33154692
Link to free article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7608548/

February 25, 2021
Correia AO, Feitosa PWG, Moreira JLS, Nogueira SÁR, Fonseca RB, Nobre MEP. **Neurological manifestations of COVID-19 and other coronaviruses: A systematic review.** Neurol Psychiatry Brain Res. 2020;37:27-32. doi:10.1016/j.npbr.2020.05.008

Objective: To describe the main neurological manifestations related to coronavirus infection in humans.
Methodology: A systematic review was conducted regarding clinical studies on cases that had neurological manifestations associated with COVID-19 and other coronaviruses. The search was carried out in the electronic databases PubMed, Scopus, Embase, and LILACS with the following keywords: "coronavirus" or "Sars-CoV-2" or "COVID-19" and "neurologic manifestations" or "neurological symptoms" or "meningitis" or "encephalitis" or "encephalopathy," following the Systematic Reviews and Meta-Analyses (PRISMA) guidelines.
Results: Seven studies were included. Neurological alterations after CoV infection may vary from 17.3% to 36.4% and, in the pediatric age range, encephalitis may be as frequent as respiratory disorders, affecting 11 % and 12 % of patients, respectively. The Investigation included 409 patients diagnosed with CoV infection who presented neurological symptoms, with median age range varying from 3 to 62 years. The main neurological alterations were headache (69; 16.8 %), dizziness (57, 13.9 %), altered consciousness (46; 11.2 %), vomiting (26; 6.3 %), epileptic crises (7; 1.7 %), neuralgia (5; 1.2 %), and ataxia (3; 0.7 %). The main presumed diagnoses were acute viral meningitis/encephalitis in 25 (6.1 %) patients, hypoxic encephalopathy in 23 (5.6 %) patients, acute cerebrovascular disease in 6 (1.4 %) patients, 1 (0.2 %) patient with possible acute disseminated encephalomyelitis, 1 (0.2 %) patient with acute necrotizing hemorrhagic encephalopathy, and 2 (1.4 %) patients with CoV related to Guillain-Barré syndrome.
Conclusion: Coronaviruses have important neurotropic potential and they cause neurological alterations that range from mild to severe. The main neurological manifestations found were headache, dizziness and altered consciousness.
PMID: 33154692

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Link to free article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7261450/

March Topic: General Vestibular Knowledge

March 4, 2021
Kaski D. **Neurological update: dizziness.** J Neurol. 2020 Jun;267(6):1864-1869. doi: 10.1007/s00415-020-09748-w. Epub 2020 Mar 4

The diagnosis and management of vertigo remains a challenge for clinicians, including general neurology. In recent years there have been advances in the understanding of established vestibular syndromes, and the development of treatments for existing vestibular diagnoses. In this 'update' I will review how our understanding of previously "unexplained" dizziness in the elderly is changing, explore novel insights into the pathophysiology of vestibular migraine, and its relationship to the newly coined term 'persistent postural perceptual dizziness', and finally discuss how a simple bedside oculomotor assessment may help identify vestibular presentations of stroke
PMID: 32130499
Link to free article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7293664/

March 11, 2021
Dougherty JM, Carney M, Emmady PD. **Vestibular Dysfunction**. 2020 Dec 12. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021

Vestibular dysfunction is a disturbance of the body's balance system. The disorder differentiated into peripheral and central causes. The symptoms of peripheral and central vestibular dysfunction can overlap, and a comprehensive physical examination can often help differentiate the two. Vestibular disorders usually present acutely. The patient's symptom complex typically consists of vertigo, nausea, vomiting, intolerance to head motion, nystagmus, unsteady gait, and postural instability. The most common form of acute peripheral vestibular dysfunction is vestibular neuronitis. The most common cause of severe central vestibular dysfunction is an ischemic stroke of the posterior fossa, which contains the brainstem and cerebellum. An acute ischemic stroke accounts for up to 25% of patients who present as central vestibular function. Since acute stroke is treated differently, it is essential to recognize this disorder. The second common cause of central vestibular dysfunction is a demyelinating disease. Studies have shown there is a small prevalence of vestibular dysfunction in patients with syncope. Syncope is a presentation of vertebral basilar artery disease with a prevalence of five percent of strokes. Symptoms of vestibular dysfunction include a variety of symptoms: vertigo, nausea and vomiting, intolerance to head motion, spontaneous nystagmus, unsteady gait, and postural instability caused by injury to peripheral or central vestibular structures. The prevalence of each of these symptoms varies, and there is no single symptom that helps identify vestibular dysfunction. The predominance of the symptoms listed above as a cluster leads to the suspicion of vestibular dysfunction. The history and physical exam is the way to differentiate peripheral from central vestibular dysfunction.

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It is necessary to identify which type of vestibular dysfunction a patient has, as this determines the therapeutic approach. The mainstay treatment for peripheral disorders is symptomatic therapy with anticholinergic medications or type 1 antihistamines. The treatment for central vestibular dysfunction caused by an ischemic stroke can include intravenous thrombolytic therapy and interventional clot retrieval in the hyperacute phase and stroke secondary prevention after that. The early identification of demyelinating disorders such as multiple sclerosis is essential so that treatment can be initiated to prevent the rapid decline and development of disabilities. This article will review the epidemiology, history and physical examination, evaluation, differential diagnosis, treatment, complications, and critical points in improving the identification of vestibular dysfunction, and differentiating peripheral from central vestibular disorders.
PMID: 32644352

March 18, 2021
Strupp M, Dlugaiczyk J, Ertl-Wagner BB, Rujescu D, Westhofen M, Dieterich M. **Vestibular Disorders**. Dtsch Arztebl Int. 2020 Apr 24;117(17):300-310. doi: 10.3238/arztebl.2020.0300.

BACKGROUND: Recent research findings have improved the understanding of the diagnosis, pathophysiology, genetics, etiology, and treatment of peripheral, central, and functional vestibular vertigo syndromes.
METHOD: A literature search, with special attention to the current classification, treatment trials, Cochrane analyses, and other meta-analyses.
RESULTS: There are internationally accepted diagnostic criteria for benign positional paroxysmal vertigo, Menière's disease, bilateral vestibulopathy, vestibular paroxysmia, and functional dizziness. Whether an acute vestibular syndrome is central or peripheral can usually be determined rapidly on the basis of the history and the clinical examination. "Cere - bellar vertigo" is a clinically important entity. For bilateral vestibulopathy, balance training is an effective treatment. For Menière's disease, preventive treatment with betahistine (48 mg and 144 mg per day) is not superior to placebo. For vestibular paroxysmia, oxcarbazepine has been shown to be effective. Treatments that are probably effective for functional dizziness include vestibular rehabilitation, cognitive behavioral therapy, and serotonin reuptake inhibitors.
CONCLUSION: The diagnostic assessment of vestibular syndromes is much easier for clinicians now that it has been internationally standardized. There is still a lack of randomized, controlled trials on the treatment of, for example, Menière's disease, vestibular migraine, and "cerebellar vertigo."
PMID: 32530417
Link to free article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7297064/

March 25, 2021
Casale J, Browne T, Murray I, Gupta G. **Physiology, Vestibular System**. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021 Jan. 2020 May 24.

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The vestibular system is a complex set of structures and neural pathways that serves a wide variety of functions that contribute to our sense of proprioception and equilibrium. These functions include the sensation of orientation and acceleration of the head in any direction with associated compensation in eye movement and posture. These reflexes are referred to as the vestibulo-ocular and vestibulospinal reflexes, respectively. The centrally located vestibular system involves neural pathways in the brain that respond to afferent input from the peripheral vestibular system in the inner ear and provide efferent signals that make these reflexes possible. Current data suggest that the vestibular system also plays a role in consciousness, and dysfunctions of the system can cause cognitive deficits related to spatial memory, learning, and navigation.
PMID: 30422573
Link to free article: https://www.ncbi.nlm.nih.gov/books/NBK532978/

April Topic: Exploring Relationship Between Dizziness & Pain

April 7, 2021
Malmström EM, Ekvall Hansson E, Hafström A, Magnusson M, Fransson PA. **Co-morbidities to Vestibular Impairments-Some Concomitant Disorders in Young and Older Adults**. Front Neurol. 2021 Jan 27;11:609928. doi: 10.3389/fneur.2020.609928.

BACKGROUND: Dizziness and pain are common complaints that often appear concomitantly, with or without a causal relationship. However, these symptoms might maintain and exacerbate each other and other co-morbidities. Therefore, adequate rehabilitation may have to include an expanded focus on other deficits and preconditions, especially in older adults and in patients.
OBJECTIVE: To understand how frequently vestibular dysfunction coincided with medical conditions and aging, we studied two categories: Study 1: patients referred to a vestibular unit and Study 2: senior members in a fitness association.
METHOD: Study 1: 49 patients [34 females/15 males; mean age 52 years (SEM 2.0)] seeking health care for balance disorders and vestibular deficits were asked in questionnaires about their perception of dizziness and pain, and emotional and functional strains. Study 2: 101 senior members in a fitness association [91 females/10 males; mean age 75 years (SEM 0.6)], were assessed for vestibular and balance deficits and for any co-morbidities. The participants were monitored for falls for 12 months after the initial assessments.
RESULT: Study 1: Co-morbidity often existed between dizziness and pain (65%). The patients reported high emotional and functional strain related to their dizziness and pain. Patients older than 60 years reported longer durations of pain ($p \leq 0.028$) but less emotional strain ($p = 0.036$), compared to younger patients. Study 2: 84% of the participants had a vestibular impairment, often without noticing any symptoms. Furthermore, 40% reported cardiovascular illnesses, 12% musculoskeletal disorders, and 63% reported other medical conditions. Forty-two percent experienced falls within 1 year after the

initial assessments (thereof 42% in the group with vestibular deficits and 38% in the group without vestibular deficits).
CONCLUSION: To enhance and preserve postural control, both in patients with vestibular deficits and in older adults, we suggest an expanded clinical perspective. Hence, we recommend detailed examinations of the vestibular system but simultaneously probing for possible co-morbidities. Since aging often entails deterioration of multimodal processes related to maintained mobility and postural stability, our results add focus on the importance of addressing balance disorders together with additional medical conditions.
PMID: 33584509
Link to free article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7873354/

April 15, 2021
Malmström, E. M., Magnusson, M., Holmberg, J., Karlberg, M., & Fransson, P. A. (2020). **Dizziness and localized pain are often concurrent in patients with balance or psychological disorders.** Scandinavian journal of pain, 20(2), 353–362

BACKGROUND AND AIMS: Symptoms of dizziness and pain are both common complaints and the two symptoms often seem to coincide. When symptoms appear concomitant for sustained periods of time the symptoms might maintain and even exacerbate each other, sometimes leading to psychological distress. In order to evaluate such comorbidity we studied patients referred to a vestibular unit and to a psychiatric outpatient clinic with respectively balance disorders and psychological issues.
METHODS: Consecutive patients referred to a vestibular unit (n = 49) and a psychiatric outpatient clinic (n = 62) answered the Dizziness Handicap Inventory (DHI) questionnaire and a questionnaire detailing occurrence of dizziness and pain.
RESULTS: The experience of dizziness and pain often coincided within individuals across both clinical populations, especially if the pain was located to the neck/shoulder or the back ($p = 0.006$). Patients who reported dizziness had significantly more often pain ($p = 0.024$); in the head ($p = 0.002$), neck/shoulders ($p = 0.003$) and feet ($p = 0.043$). Moreover, patients who reported dizziness stated significantly higher scoring on emotional ($p < 0.001$) and functional ($p < 0.001$) DHI sub-scales. Furthermore, patients who reported an accident in their history suffered significantly more often from dizziness ($p = 0.039$) and pain ($p < 0.001$); in the head ($p < 0.001$), neck/shoulders ($p < 0.001$) and arms ($p = 0.045$) and they scored higher on the emotional ($p = 0.004$) and functional ($p = 0.002$) DHI sub-scales.
CONCLUSIONS: The findings suggest comorbidity to exist between dizziness and neck/shoulder or back pain in patients seeking health care for balance disorders or psychological issues. Patients suffering from dizziness and pain, or with both symptoms, also reported higher emotional and functional strain. Thus, healthcare professionals should consider comorbidity when determining diagnosis and consequent measures. Implications Clinicians need to have a broader "receptive scope" in both history and clinical examinations, and ask for all symptoms. Although the patients in this study visited a vestibular unit respectively a psychological clinic, they commonly reported pain conditions when explicitly asked for

this symptom. A multimodal approach is thus to favor, especially when the symptoms persist, for the best clinical management.
PMID: 31881001

April 22, 2021
Sarna, B., Risbud, A., Lee, A., Muhonen, E., Abouzari, M., & Djalilian, H. R. (2021). **Migraine Features in Patients with Persistent Postural-Perceptual Dizziness.** The Annals of otology, rhinology, and laryngology, 34894211007233. Advance online publication.

OBJECTIVES: To evaluate the presence of migraine features in patients with persistent postural-perceptual dizziness (PPPD).
METHODS: In a retrospective survey study, consecutive patients presenting to a tertiary care neurotology clinic during an 18-month period were given questionnaires about headache and dizziness symptoms. The survey responses plus history and examination of the patient were used to diagnose patients with PPPD. The prevalence of migraine headache, vestibular migraine (VM), and migraine characteristics was evaluated.
RESULTS: In total, 36 subjects with PPPD were included in the study. The mean age of the subjects was 56 ± 16 years with a female (72%) predominance. A total of 19 (53%) patients met the International Classification of Headache Disorders criteria for migraine headache, and 6 of those (17%) met the criteria for definite VM. Of the patients who did not meet full migraine headache criteria, 6 (17%) patients met 4 of 5 criteria, and 5 (14%) patients met 3 of 5 criteria. There was no significant difference between PPPD patients who fulfilled full migraine headache criteria and those who did not in sensitivity to light, sound, smells, weather changes, feelings of mental fog/confusion, and sinus pain/facial pressure.
CONCLUSIONS: This study demonstrates that a majority of patients with PPPD fulfill the criteria for migraine headache. A large proportion of PPPD patients who do not meet the full criteria for migraine headache still meet a majority of the migraine headache criteria. This suggests an association between the 2 conditions. PPPD may be a part of the spectrum of otologic migraine, where migraine manifests as otologic symptoms.
PMID: 33813915

April 28, 2021
Iglebekk W, Tjell C, Borenstein P. **Pain and other symptoms in patients with chronic benign paroxysmal positional vertigo (BPPV).** Scand J Pain. 2013 Oct 1;4(4):233-240. doi: 10.1016/j.sjpain.2013.06.004

Background and aim: A diagnosis of chronic benign paroxysmal positional vertigo (BPPV) is based on brief attacks of rotatory vertigo and concomitant nystagmus elicited by rapid changes in head position relative to gravity. However, the clinical course of BPPV may vary considerably from a self-limiting to a persisting and/or recurrent disabling problem. The authors' experience is that the most common complaints of patients with chronic BPPV are nautical vertigo or dizziness with other symptoms including neck pain, headache, widespread musculoskeletal pain, fatigue, and visual disturbances. Trauma is

believed to be the major cause of BPPV in individuals younger than fifty years. Chronic BPPV is associated with high morbidity. Since these patients often suffer from pain and do not have rotatory vertigo, their symptoms are often attributed to other conditions. The aim of this study was to investigate possible associations between these symptoms and chronic BPPV. Methods During 2010 a consecutive prospective cohort observational study was performed. Diagnostic criteria: (A) BPPV diagnosis confirmed by the following: (1) a specific history of vertigo/dizziness evoked by acceleration/deceleration, (2) nystagmus in the first position of otolith repositioning maneuvers, and (3) appearing and disappearing nystagmus during the repositioning maneuvers; (B) the disorder has persisted for at least six months. (C) Normal MRI of the cerebrum.

Exclusion criteria: (A) Any disorder of the central nervous system (CNS), (B) migraine, (C) active Ménière's disease, and (D) severe eye disorders. Symptom questionnaire ('yes or no' answers during a personal interview) and Dizziness Handicap Inventory (DHI) were used. Results We included 69 patients (20 males and 49 females) with a median age of 45 years (range 21-68 years). The median duration of the disease was five years and three months. The video-oculography confirmed BPPV in more than one semicircular canal in all patients. In 15% there was a latency of more than 1 min before nystagmus occurred. The Dizziness Handicap Inventory (DHI) median score was 55.5 (score >60 indicates a risk of fall). Seventy-five percent were on 50-100% sick leave. Eighty-one percent had a history of head or neck trauma. Nineteen percent could not recall any history of trauma. In our cohort, nautical vertigo and dizziness (81%) was far more common than rotatory vertigo (20%). The majority of patients (87%) reported pain as a major symptom: neck pain (87%), headache (75%) and widespread pain (40%). Fatigue (85%), visual disturbances (84%), and decreased concentration ability (81%) were the most frequently reported symptoms. In addition, unexpected findings such as involuntary movements of the extremities, face, neck or torso were found during otolith repositioning maneuvers (12%). We describe one case, as an example, how treatment of his BPPV also resolved his chronic, severe pain condition. Conclusion This observational study demonstrates a likely connection between chronic BPPV and the following symptoms: nautical vertigo/dizziness, neck pain, headache, widespread pain, fatigue, visual disturbances, cognitive dysfunctions, nausea, and tinnitus. Implications Patients with complex pain conditions associated with nautical vertigo and dizziness should be evaluated with the Dizziness Handicap Inventory (DHI)-questionnaire which can identify treatable balance disorders in patients with chronic musculoskeletal pain.
PMID: 29913653

May Topic: Technology in Vestibular Rehabilitation

May 6, 2021
Parrington, L., Jehu, D. A., Fino, P. C., Stuart, S., Wilhelm, J., Pettigrew, N., Murchison, C. F., El-Gohary, M., VanDerwalker, J., Pearson, S., Hullar, T., Chesnutt, J. C., Peterka, R. J., Horak, F. B., & King, L. A. (2020). **The sensor technology and rehabilitative timing (START) protocol: A randomized controlled trial for the rehabilitation of mild traumatic brain injury.** Physical Therapy, 100(4), 687–697
BACKGROUND: Clinical practice for rehabilitation after mild traumatic brain injury (mTBI) is variable, and guidance on when to initiate physical therapy is lacking. Wearable sensor technology may aid clinical

assessment, performance monitoring, and exercise adherence, potentially improving rehabilitation outcomes during unsupervised home exercise programs.
OBJECTIVE: The objectives of this study were to: (1) determine whether initiating rehabilitation earlier than typical will improve outcomes after mTBI, and (2) examine whether using wearable sensors during a home-exercise program will improve outcomes in participants with mTBI.
DESIGN: This was a randomized controlled trial.
SETTING: This study will take place within an academic hospital setting at Oregon Health & Science University and Veterans Affairs Portland Health Care System, and in the home environment.
PARTICIPANTS: This study will include 160 individuals with mTBI.
INTERVENTION: The early intervention group (n = 80) will receive one-on-one physical therapy 8 times over 6 weeks and complete daily home exercises. The standard care group (n = 80) will complete the same intervention after a 6- to 8-week wait period. One-half of each group will receive wearable sensors for therapist monitoring of patient adherence and quality of movements during their home exercise program.
MEASUREMENTS: The primary outcome measure will be the Dizziness Handicap Inventory score. Secondary outcome measures will include symptomatology, static and dynamic postural control, central sensorimotor integration posturography, and vestibular-ocular-motor function.
LIMITATIONS: Potential limitations include variable onset of care, a wide range of ages, possible low adherence and/or withdrawal from the study in the standard of care group, and low Dizziness Handicap Inventory scores effecting ceiling for change after rehabilitation.
CONCLUSIONS: If initiating rehabilitation earlier improves primary and secondary outcomes post-mTBI, this could help shape current clinical care guidelines for rehabilitation. Additionally, using wearable sensors to monitor performance and adherence may improve home exercise outcomes
PMID: 31951263

May 13, 2021
Gawronska A, Pajor A, Zamyslowska-Szmytke E, Rosiak O, Jozefowicz-Korczynska M. **Usefulness of Mobile Devices in the Diagnosis and Rehabilitation of Patients with Dizziness and Balance Disorders: A State of the Art Review.** Clin Interv Aging. 2020 Dec 22;15:2397-2406. doi: 10.2147/CIA.S289861

OBJECTIVE: The gold standard for objective body posture examination is posturography. Body movements are detected through the use of force platforms that assess static and dynamic balance (conventional posturography). In recent years, new technologies like wearable sensors (mobile posturography) have been applied during complex dynamic activities to diagnose and rehabilitate balance disorders. They are used in healthy people, especially in the aging population, for detecting falls in the older adults, in the rehabilitation of different neurological, osteoarticular, and muscular system diseases, and in vestibular disorders. Mobile devices are portable, lightweight, and less expensive than conventional posturography. The vibrotactile system can consist of an accelerometer (linear acceleration measurement), gyroscopes (angular acceleration measurement), and magnetometers (heading measurement, relative to the Earth's magnetic field). The sensors may be mounted to the

trunk (most often in the lumbar region of the spine, and the pelvis), wrists, arms, sternum, feet, or shins. Some static and dynamic clinical tests have been performed with the use of wearable sensors. Smartphones are widely used as a mobile computing platform and to evaluate the results or monitor the patient during the movement and rehabilitation. There are various mobile applications for smartphone-based balance systems. Future research should focus on validating the sensitivity and reliability of mobile device measurements compared to conventional posturography.
CONCLUSION: Smartphone based mobile devices are limited to one sensor lumbar level posturography and offer basic clinical evaluation. Single or multi sensor mobile posturography is available from different manufacturers and offers single to multi-level measurements, providing more data and in some instances even performing sophisticated clinical balance tests.
PMID: 33376315
Link to Free Article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7764625/

May 27, 2021
Zhang, Y., Wang, H., Yao, Y., Liu, J., Sun, X., & Gu, D. (2021). **Walking stability in patients with benign paroxysmal positional vertigo: an objective assessment using wearable accelerometers and machine learning.** Journal of NeuroEngineering & Rehabilitation, 18(1), 1–9.

BACKGROUND: Benign paroxysmal positional vertigo (BPPV) is one of the most common peripheral vestibular disorders leading to balance difficulties and increased fall risks. This study aims to investigate the walking stability of BPPV patients in clinical settings and propose a machine-learning-based classification method for determining the severity of gait disturbances of BPPV.
METHODS: Twenty-seven BPPV outpatients and twenty-seven healthy subjects completed level walking trials at self-preferred speed in clinical settings while wearing two accelerometers on the head and lower trunk, respectively. Temporo-spatial variables and six walking stability related variables [root mean square (RMS), harmonic ratio (HR), gait variability, step/stride regularity, and gait symmetry] derived from the acceleration signals were analyzed. A support vector machine model (SVM) based on the gait variables of BPPV patients were developed to differentiate patients from healthy controls and classify the handicapping effects of dizziness imposed by BPPV.
RESULTS: The results showed that BPPV patients employed a conservative gait and significantly reduced walking stability compared to the healthy controls. Significant different mediolateral HR at the lower trunk and anteroposterior step regularity at the head were found in BPPV patients among mild, moderate, and severe DHI (dizziness handicap inventory) subgroups. SVM classification achieved promising accuracies with area under the curve (AUC) of 0.78, 0.83, 0.85 and 0.96 respectively for differentiating patients from healthy controls and classifying the three stages of DHI subgroups. Study results suggest that the proposed gait analysis that is based on the coupling of wearable accelerometers and machine learning provides an objective approach for assessing gait disturbances and handicapping effects of dizziness imposed by BPPV.
PMID: 33789693
Link to Free Article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8011133/

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May 27, 2021

Gulcelik, G. E., Tarakci, D., Soyuyuce, O. G., Gumus, Z. G., Korkut, N., & Algun, Z. C. (2020). **Research on the effects of a web-based system with oculomotor and optokinetic stimuli on vestibular rehabilitation**. American Journal of Physical Medicine & Rehabilitation.

OBJECTIVE: The variety and use of technologies used in vestibular rehabilitation is very limited. The purpose of this study was to investigate the effects of a web-based system on vestibular rehabilitation in patients with vestibular hypofunction.
DESIGN: 20 patients with unilateral vestibular hypofunction were randomly assigned to two groups. Conventional vestibular rehabilitation was applied to the control group, whereas the study group received treatment with the web-based system supporting the vestibulo-ocular reflex with oculomotor and optokinetic stimulus (SVORE-Simulation of Vestibulo-Ocular Reflex Exercises). Vestibular and balance tests, oculomotor level, Tampa Kinesiophobia Scale (TKS) and Dizziness Handicap Inventory (DHI) were used to evaluate the efficacy treatment's.
RESULTS: Vestibular symptoms and findings, balance tests, oculomotor functions, Tampa Kinesiophobia Scale and Dizziness Handicap Inventory improved significantly in both of the groups after the interventions ($p<0.05$). In the intergroup analysis, improvement was found in eyes closed Romberg, semi-tandem and left one-foot position balance tests in favor of the study group ($p<0.05$).
CONCLUSION: The new vestibular technology, SVORE was found to be effective in vestibular rehabilitation.
PMID: 32889859

June Topic: Peripheral Vestibular Dysfunctions and Functional Outcome Measures

June 3, 2021

Kim KJ, Gimmon Y, Millar J, Brewer K, Serrador J, Schubert MC. **The Instrumented Timed Up and Go Test Distinguishes Turning Characteristics in Vestibular Hypofunction.** Phys Ther. 2021 Mar 26:pzab103. doi: 10.1093/ptj/pzab103.

OBJECTIVE: Deficits in vestibular function increase the risk for falls while turning. However, the clinical assessment of turning in patients with vestibular dysfunction is lacking, and evidence is limited that identifies the effectiveness of vestibular physical therapy in improving turning performance. The purpose of this study was to quantify walking and turning performance during the instrumented Timed "Up and Go" (TUG) test using body-worn inertial measurement units (IMUs). Novel instrumented TUG parameters were investigated for ability to distinguish patients with unilateral vestibular deafferentation (UVD) from control groups and discriminate the differences in turning parameters of patients with UVD following vestibular physical therapy.

METHODS: Thirty-eight patients were recruited following UVD surgery (26 age-matched veteran patient controls with reports of dizziness not from a peripheral vestibular origin, and 12 age-matched healthy controls). Participants were donned with IMUs and given verbal instructions to complete the TUG test as fast as safely possible. The IMU-instrumented and automated assessment of the TUG test provided component-based TUG parameters, including the novel walk:turn ratio. Among the patients with UVD, 19 completed an additional instrumented TUG testing after vestibular physical therapy.
RESULTS: The walk:turn time ratio showed that turning performance in patients with UVD before rehabilitation is significantly more impaired than both the patients with nonperipheral conditions and healthy controls. Vestibular rehabilitation significantly improved turning performance and "normalized" their walk:turn time ratio compared with healthy controls. The duration of the straight walking component in patients with UVD before vestibular physical therapy, however, was not significantly different compared with that component in people after vestibular physical therapy and in healthy controls.
CONCLUSION: The IMU-instrumented TUG test can be used to distinguish patients with vestibular deafferentation and to objectively quantify the change in their turning performance after vestibular physical therapy.
IMPACT: The IMU-based instrumented TUG parameters have the potential to quantify the efficacy of vestibular physical therapy and be adopted in the clinic.
PMID: 33774661

June 10, 2021
Herssens N, Swinnen E, Dobbels B, Van de Heyning P, Van Rompaey V, Hallemans A, Vereeck L. **The Relationship Between the Activities-Specific Balance Confidence Scale and Balance Performance, Self-Perceived Handicap, and Fall Status in Patients With Peripheral Dizziness or Imbalance.** Otol Neurotol. 2021 Apr 14. doi: 10.1097/MAO.0000000000003166. Epub ahead of print.

OBJECTIVE: Describe the relationship between the Activities-Specific Balance Confidence (ABC) scale and Dizziness Handicap Inventory (DHI) with balance performance, as well as fall status in patients with peripheral vestibular disorders.
STUDY DESIGN: Retrospective.
SETTING: Outpatient balance clinic, tertiary referral center.
PATIENTS: Data from 97 patients (age: 54.8 ± 12.3 yrs; 48 women) with dizziness or imbalance symptoms of peripheral vestibular origin were used for analysis.
INTERVENTIONS: /.
MAIN OUTCOME MEASURES: ABC-scores, DHI-scores, static and dynamic balance tests, and fall status of the past 4 weeks, 2 months, and 6 months before the time of measurement were collected. Spearman's rho correlations, $\chi 2$ with post-hoc testing, and Kruskal-Wallis with post-hoc Mann-Whitney U test results were interpreted.
RESULTS: The ABC- and DHI-scores show moderate correlations with static balance (ABC: r = 0.44; DHI: r = -0.34) and dynamic balance tests (ABC: r = [-0.47;0.56]; DHI: r = [-0.48;0.39]) and a strong inverse

correlation with each other (ABC: 70 ± 25; DHI: 33 ± 26; r = -0.84). Related to fall status, weak correlations were found (ABC: r = [-0.29;-0.21]; DHI: r = [0.29;0.33]). Additional results show that subjects in the low-level functioning (ABC) or severe self-perceived disability (DHI) categories have a poorer balance assessed by standing balance, Timed-Up-and-Go and Functional Gait Assessment and are more likely to have experienced multiple falls.
CONCLUSIONS: The ABC-scale and DHI showed a strong convergent validity, additionally the ABC-scale showed a better concurrent validity with balance performances and the DHI with fall history. In general, patients with peripheral vestibular impairments reporting a lower self-confidence or a more severe self-perceived disability show worse balance performances and a higher fall incidence.
PMID: 33859139

June 17, 2021
Said M, Lee J, Moshtaghi O, Saliba J, Richardson AJW, Ngo V, Mehranpour P, Schwartz MS, Friedman RA. **The Relationship Between the Functional Gait Assessment and Quality-of-Life Data in Patients Undergoing Vestibular Schwannoma Resection**. Otol Neurotol. 2021 Mar 19. doi: 10.1097/MAO.0000000000003137. Epub ahead of print.

OBJECTIVE: To examine the relationship between the Functional Gait Assessment (FGA) and quality of life (QOL) measurements relating to balance before and after vestibular schwannoma (VS) resection and to assess the role of preoperative FGA in predicting postoperative QOL.
STUDY DESIGN: A prospective clinical study of adult patients undergoing VS resection between September 2018 and December 2019. FGA was administered 1 week before and after surgery. Dizziness Handicap Inventory (DHI) and Penn Acoustic Neuroma Quality of Life (PANQOL) were administered preoperatively and at 3 months postoperatively.
SETTING: Single tertiary center.
PATIENTS: Patients (age ≥ 18 years old) with VS undergoing microsurgical resection. Excluded were patient with previous surgery or radiation.
INTERVENTION: VS resection.
MAIN OUTCOMES AND MEASURES: Primary outcome: correlation between FGA and QOL surveys. Secondary outcome: correlation between preoperative measurements of balance and postoperative PANQOL.
RESULTS: One hundred thirty-eight patients were analyzed (mean age: 48 years old, 65.9% female). The translabyrinthine approach was most commonly performed. Under multivariate analysis, preoperative FGA significantly correlated with preoperative PANQOL balance score ($p < 0.0001$), preoperative PANQOL total score ($p = 0.0002$), and preoperative DHI ($p < 0.0001$). However, postoperative FGA did not significantly correlate with postoperative PANQOL balance or total scores ($p = 0.446$ and $p = 0.4$, respectively), or postoperative DHI ($p = 0.3$). Univariate analysis demonstrated that preoperative DHI and preoperative FGA were predictive of changes in postoperative PANQOL balance and total scores. However under multivariate analysis, preoperative FGA did not predict changes in postoperative PANQOL balance or total score ($p = 0.24$; $p = 0.28$, respectively). Preoperative DHI remained predictive

of changes in postoperative PANQOL balance (p = 0.03) score but not of postoperative PANQOL total score (p = 0.37).
CONCLUSIONS: Although FGA and QOL data significantly correlated in the preoperative setting, our results did not suggest that preoperative FGA can be used to determine postoperative QOL. Additionally, the lack of correlation between FGA and QOL measurements in the acute postoperative setting suggests that further research is needed to determine contributors to postoperative QOL
PMID: 33741817

June 25, 2021
Allum JHJ, Rust HM, Honegger F. **Functional Testing of Vestibulo-Spinal Contributions to Balance Control: Insights From Tracking Improvement Following Acute Bilateral Peripheral Vestibular Loss.** Front Neurol. 2019 May 28;10:550. doi: 10.3389/fneur.2019.00550.

BACKGROUND: A battery of stance and gait tasks can be used to quantify functional deficits and track improvement in balance control following peripheral vestibular loss. An improvement could be due to at least 3 processes: partial peripheral recovery of sensory responses eliciting canal or otolith driven vestibular reflexes; central compensation of vestibular reflex gains, including substitution of intact otolith responses for pathological canal responses; or sensory substitution of visual and proprioceptive inputs for vestibular contributions to balance control.
RESULTS: We describe the presumed action of all 3 processes observed for a case of sudden incapacitating acute bilateral peripheral loss probably due to vestibular neuritis. Otolith responses were largely unaffected. However, pathological decreases in all canal-driven vestibular ocular reflex (VOR) gains were observed. After 3 months of vestibular rehabilitation, balance control was normal but VOR gains remained low.
CONCLUSIONS: This case illustrates the difficulty in predicting balance control improvements from tests of the 10 vestibular end organs and emphasizes the need to test balance control function directly in order to determine if balance control has improved and is normal again despite remaining vestibular sensory deficits. This case also illustrates that the presence of residual otolithic function may be crucial for balance control improvement in cases of bilateral vestibular hypofunction.
PMID: 31191439
Link to free article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6546919/

July Topic: Articles Co-Authored by Michael Schubert, PT, Ph.D.

July 8, 2021
Rinaudo CN, Schubert MC, Figtree WVC, Cremer PD, Migliaccio AA. **Human Vestibulo-Ocular Reflex Adaptation Reduces when Training Demand Variability Increases.** J Assoc Res Otolaryngol. 2021 Apr;22(2):193-206. doi: 10.1007/s10162-020-00775-y. Epub 2020 Oct 22.

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One component of vestibular rehabilitation in patients with vestibulo-ocular reflex (VOR) hypofunction is gaze-stabilizing exercises that seek to increase (adapt) the VOR response. These prescribed home-based exercises are performed by the patient and thus their use/training is inherently variable. We sought to determine whether this variability affected VOR adaptation in ten healthy controls (× 2 training only) and ten patients with unilateral vestibular hypofunction (× 1 and × 2 training). During × 1 training, patients actively (self-generated, predictable) move their head sinusoidally while viewing a stationary fixation target; for × 2 training, they moved their outstretched hand anti-phase with their head rotation while attempting to view a handheld target. We defined the latter as manual × 2 training because the subject manually controls the target. In this study, head rotation frequency during training incrementally increased 0.5-2 Hz over 20 min. Active and passive (imposed, unpredictable) sinusoidal (1.3-Hz rotations) and head impulse VOR gains were measured before and after training. We show that for controls, manual × 2 training resulted in significant sinusoidal and impulse VOR adaptation of ~ 6 % and ~ 3 %, respectively, though this was ~two-thirds lower than increases after computer-controlled × 2 training (non-variable) reported in a prior study. In contrast, for patients, there was an increase in impulse but not sinusoidal VOR response after a single session of manual × 2 training. Patients had more than double the variability in VOR demand during manual × 2 training compared to controls, which could explain why adaptation was not significant in patients. Our data suggest that the clinical × 1 gaze-stabilizing exercise is a weak stimulus for VOR adaptation.
PMID: 33090309

July 16, 2021
Rinaudo CN, Schubert MC, Cremer PD, Figtree WVC, Todd CJ, Migliaccio AA. **Once-Daily Incremental Vestibular-Ocular Reflex Adaptation Training in Patients With Chronic Peripheral Vestibular Hypofunction: A 1-Week Randomized Controlled Study**. J Neurol Phys Ther. 2021 Apr 1;45(2):87-100. doi: 10.1097/NPT.0000000000000348

BACKGROUND AND PURPOSE: This was a double-blinded randomized controlled study to investigate the effects of once-daily incremental vestibulo-ocular reflex (VOR) training over 1 week in people with chronic peripheral vestibular hypofunction.
METHODS: A total of 24 patients with peripheral vestibular hypofunction were randomly assigned to intervention (n = 13) or control (n = 11) groups. Training consisted of either x1 (control) or incremental VOR adaptation exercises, delivered once daily for 15 minutes over 4 days in 1 week. Primary outcome: VOR gain with video-oculography. Secondary outcomes: Compensatory saccades measured using scleral search coils, dynamic visual acuity, static balance, gait, and subjective symptoms. Between-group differences were analyzed with a linear mixed-model with repeated measures.
RESULTS: There was a difference in the VOR gain increase between groups ($P < 0.05$). The incremental training group gain increased during active (13.4% ± 16.3%) and passive (12.1% ± 19.9%) head impulse testing ($P < 0.02$), whereas it did not for the control group ($P = 0.59$). The control group had reduced compensatory saccade latency ($P < 0.02$). Both groups had similarly improved dynamic visual acuity scores ($P < 0.05$). Both groups had improved dynamic gait index scores ($P < 0.002$); however, only the

incremental group had improved scores for the 2 walks involving head oscillations at approximately 2 Hz (horizontal: $P < 0.05$; vertical: $P < 0.02$), increased gait speed ($P < 0.02$), and step length ($P < 0.01$) during normal gait, and improved total Dizziness Handicap Inventory ($P < 0.05$).
CONCLUSIONS: Our results suggest incremental VOR adaptation significantly improves gain, gait with head rotation, balance during gait, and symptoms in patients with chronic peripheral vestibular hypofunction more so than conventional x1 gaze-stabilizing exercises.
Video Abstract available for more insights from the authors (see the Video, Supplemental Digital Content 1, available at: http://links.lww.com/JNPT/A336).
PMID: 33675600

July 22, 2021
Chang TP, Schubert MC. **Convergence Vestibulo-ocular Reflex in Unilateral Vestibular Hypofunction: Behavioral Evidence in Support of a Novel Gaze Stability Exercise**. J Neurol Phys Ther. 2021 Jan;45(1):3-11. doi: 10.1097/NPT.0000000000000335. PMID: 33065632

BACKGROUND AND PURPOSE: Convergence of the eyes during head rotation increases the gain (eye velocity/head velocity) of the vestibulo-ocular reflex (VOR). We sought to know whether convergence would increase the VOR gain (mean + SD) in unilateral vestibular hypofunction (UVH).
METHODS: Vestibulo-ocular reflex gain during ipsi- and contralesional horizontal head rotation at near (15 cm) and far (150 cm) targets was measured in 22 subjects with UVH and 12 healthy controls. Retinal slip was estimated (retinal slip index [RSI]) as the difference between ideal VOR gain (no retinal slip) and the actual VOR gain.
RESULTS: Convergence did not significantly enhance VOR gain for ipsilesional rotation (mean difference, 0.04; 95% confidence interval [CI], -0.01 to 0.09), near viewing (0.77 ± 0.34) versus far viewing (0.72 ± 0.29), yet the VOR gain during contralesional rotation was greater for near viewing (1.20 ± 0.23) than for far viewing (0.97 ± 0.21; mean difference, 0.23; 95% CI, 0.13-0.32). In the 36% of subjects with recovery of their ipsilesional VOR gain, the vergence effect trended to recover (far VOR gain: 1.06 ± 0.17 vs near VOR gain 1.16 ± 0.21; mean difference, 0.10; 95% CI, -0.02 to 0.22). Ipsilesional head rotation induced greater retinal slip for near (RSI = 0.90 ± 0.34) targets than for far targets (RSI = 0.35 ± 0.29; mean difference, 0.56; 95% CI, 0.51-0.61).
DISCUSSION AND CONCLUSIONS: The convergence-mediated VOR gain enhancement is preserved during contralesional but impaired during ipsilesional head rotation. Recovery of ipsilesional passive VOR gain does not equate to restored convergence enhancement, although it did increase ∼10%. These data suggest head motion viewing near targets will increase retinal slip, which warrants consideration as a gaze stability exercise for subjects with UVH.Video Abstract available for more insights from the authors (see Video, Supplemental Digital Content 1, available at: http://links.lww.com/JNPT/A325).
PMID: 33065632

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July 29, 2021

Muntaseer Mahfuz M, Schubert MC, Figtree WVC, Todd CJ, Migliaccio AA. **Human Vestibulo-Ocular Reflex Adaptation Training: Time Beats Quantity.** J Assoc Res Otolaryngol. 2018 Dec;19(6):729-739. doi: 10.1007/s10162-018-00689-w. Epub 2018 Sep 24.

The vestibulo-ocular reflex (VOR) is the main gaze stabilising system during rapid head movements. The VOR is highly plastic and its gain (eye/head velocity) can be increased via training that induces an incrementally increasing retinal image slip error signal to drive VOR adaptation. Using the unilateral incremental VOR adaptation technique and horizontal active head impulses as the vestibular stimulus, we sought to determine the factors important for VOR adaptation including: the total training time, ratio and number of head impulses to each side (adapting and non-adapting sides; the adapting side was pseudo-randomised left or right) and exposure time to the visual target during each head impulse. We tested 11 normal subjects, each over 5 separate sessions and training protocols. The basic training protocol (protocol one) consisted of unilateral incremental VOR adaptation training lasting 15 min with the ratio of head impulses to each side 1:1. Each protocol varied from the basic. For protocol two, the ratio of impulses were in favour of the adapting side by 2:1. For protocol three, all head impulses were towards the adapting side and the training only lasted 7.5 min. For protocol four, all impulses were towards the adapting side and lasted 15 min. For protocol five, all head impulses were to the adapting side and the exposure time to the visual target during each impulse was doubled. We measured the active and passive VOR gains before and after the training. Albeit with small sample size, our data suggest that the total training time and the visual target exposure time for each head impulse affected adaptation, whereas the total number and repetition rate of head impulses did not. These data have implications for vestibular rehabilitation, suggesting that quality and duration of VOR adaptation exercises are more important than rapid repetition of exercises.
PMID: 30251187
Link to Free Article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6249163/

August Topic: Motor Learning and the Vestibular System

August 6, 2021

Patel, M, Roberts, E, Arshad, Q, Bunday, K, Golding, JF, Kaski, D, Bronstein, AM. **The "broken escalator" phenomenon: Vestibular dizziness interferes with locomotor adaptation.** J Vestib Res. 2020; 30(2):81-94. doi: 10.3233/VES-200693. PMID: 32116265 DOI: 10.3233/VES-200693

BACKGROUND: Although vestibular lesions degrade postural control we do not know the relative contributions of the magnitude of the vestibular loss and subjective vestibular symptoms to locomotor adaptation.
OBJECTIVE: To study how dizzy symptoms interfere with adaptive locomotor learning.

METHODS: We examined patients with contrasting peripheral vestibular deficits, vestibular neuritis in the chronic stable phase (n = 20) and strongly symptomatic unilateral Meniere's disease (n = 15), compared to age-matched healthy controls (n = 15). We measured locomotor adaptive learning using the "broken escalator" aftereffect, simulated on a motorised moving sled.
RESULTS: Patients with Meniere's disease had an enhanced "broken escalator" postural aftereffect. More generally, the size of the locomotor aftereffect was related to how symptomatic patients were across both groups. Contrastingly, the degree of peripheral vestibular loss was not correlated with symptom load or locomotor aftereffect size. During the MOVING trials, both patient groups had larger levels of instability (trunk sway) and reduced adaptation than normal controls.
CONCLUSION: Dizziness symptoms influence locomotor adaptation and its subsequent expression through motor aftereffects. Given that the unsteadiness experienced during the "broken escalator" paradigm is internally driven, the enhanced aftereffect found represents a new type of self-generated postural challenge for vestibular/unsteady patients.
PMID: 32116265

August 12, 2021

Maheu M, Behtani L, Nooristani M, Delcenserie A, Champoux F. **Enhanced vestibulo-ocular reflex suppression in dancers during passive high-velocity head impulses.** Exp Brain Res. 2019;237(2):411-416. doi:10.1007/s00221-018-5431-z

The vestibulo-ocular reflex (VOR) is responsible for stabilizing images on the fovea during head movements. However, in some situations, one needs to suppress the VOR to be able to follow a target moving along with the head. Evidence suggests that the visual mechanism underlying VOR suppression can be modulated by experience. Unfortunately, the non-visual mechanism underlying VOR suppression has never been examined in dancers and, consequently, it is still unsure whether dance training can enhance eye-head tracking accuracy. The goal of the present study was to look at the influence of dance training on the VOR suppression during passive head impulses. Twenty-four individuals participated, 12 controls and 12 dancers. VOR and VOR suppression were assessed using a head impulse paradigm as well as a suppression head impulse test paradigm (SHIMP) with video head impulse test, respectively. The results suggest that dancers display a significantly reduced VOR gain during the SHIMP at 60 ms in comparison to controls. Moreover, dancers with more than 10 years of dance training exhibited a significantly reduced VOR gain during the SHIMP at 60 ms. Overall, the results suggest that dance training improves VOR suppression, but also modulates VOR suppression abilities. Although studies are needed to shed light on the possible mechanisms involved in the modulation of the VOR gain, the observed changes in dancers' vestibulo-cerebellum and its role in the modulation of the VOR gain makes the cerebellar-vestibular nuclei pathway a possible model to explain the present results.
PMID: 30426147

August 22, 2021

Vestibular Rehabilitation SIG
Archived Abstract of the Week
for the year 2021

Grosch M, Lindner M, Bartenstein P, et al. **Dynamic whole-brain metabolic connectivity during vestibular compensation in the rat.** Neuroimage. 2021;226:117588. doi:10.1016/j.neuroimage.2020.117588

Unilateral damage to the inner ear results in an acute vestibular syndrome, which is compensated within days to weeks due to adaptive cerebral plasticity. This process, called central vestibular compensation (VC), involves a wide range of functional and structural mechanisms at the cellular and network level. The short-term dynamics of whole-brain functional network recruitment and recalibration during VC has not been depicted in vivo. The purpose of this study was to investigate the interplay of separate and distinct brain regions and in vivo networks in the course of VC by sequential [18F]-FDG-PET-based statistical and graph theoretical analysis with the aim of revealing the metabolic connectome before and 1, 3, 7, and 15 days post unilateral labyrinthectomy (UL) in the rat. Temporal changes in metabolic brain connectivity were determined by Pearson's correlation ($|r| > 0.5$, $p < 0.001$) of regional cerebral glucose metabolism (rCGM) in 57 segmented brain regions. Metabolic connectivity analysis was compared to univariate voxel-wise statistical analysis of rCGM over time and to behavioral scores of static and dynamic sensorimotor recovery. Univariate statistical analysis revealed an ipsilesional relative rCGM decrease (compared to baseline) and a contralesional rCGM increase in vestibular and limbic networks and an increase in bilateral cerebellar and sensorimotor networks. Quantitative analysis of the metabolic connections showed a maximal increase from baseline to day 3 post UL (interhemispheric: 2-fold, ipsilesional: 3-fold, contralesional: 12-fold) and a gradual decline until day 15 post UL, which paralleled the dynamics of vestibular symptoms. In graph theoretical analysis, an increase in connectivity occurred especially within brain regions associated with brainstem-cerebellar and thalamocortical vestibular networks and cortical sensorimotor networks. At the symptom peak (day 3 post UL), brain networks were found to be organized in large ensembles of distinct and highly connected hubs of brain regions, which separated again with progressing VC. Thus, we found rapid changes in network organization at the subcortical and cortical level and in both hemispheres, which may indicate an initial functional substitution of vestibular loss and subsequent recalibration and reorganization of sensorimotor networks during VC.
PMID: 33249212

August 27, 2021
Dordevic M, Taubert M, Müller P, Kaufmann J, Hökelmann A, Müller NG. **Brain Gray Matter Volume Is Modulated by Visual Input and Overall Learning Success but Not by Time Spent on Learning a Complex Balancing Task**. J Clin Med. 2018;8(1):9. Published 2018 Dec 21. doi:10.3390/jcm8010009

To better understand the process of neuroplasticity, this study assesses brain changes observed by voxel-based morphometry (VBM) in response to two different learning conditions. Twenty-two young, healthy subjects learned slacklining, a complex balancing task, with either their eyes open (EO, n = 11) or their eyes closed (EC, n = 11). The learning took place three times per week for four weeks, with learning periods of 1 hour, providing a total of 12 hours of learning. The scanning and testing protocols were

applied at three time-points: (1) immediately before learning (baseline), (2) immediately afterwards (post-test), and (3) two months afterwards (follow-up). The EO group performed better on the task-specific test. Significant group*time interaction effects were found in sensory-motor areas at the post-test, with increases in the EO group only. The results suggest that VBM-observed brain changes in response to learning a complex balancing task vary depending on the learning success and the availability of visual input, and not solely on the amount of time spent on learning. These findings should be taken into account by future studies using similar methodologies.
PMID: 30577582
Link to free article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6352186/

September Topic: Vestibular Implications in Multiple Sclerosis

September 2, 2021
Cochrane, G. D., Christy, J. B., & Motl, R. W. (2021). **Comprehensive Clinical Assessment of Vestibular Function in Multiple Sclerosis.** Journal of Neurologic Physical Therapy : JNPT, 45(3), 228–234. https://doi.org/10.1097/NPT.0000000000000358

BACKGROUND AND PURPOSE: Balance disorders and dizziness are common in people with multiple sclerosis (MS), suggesting dysfunction of the vestibular system. Evaluating how people with MS perform on objective clinical vestibular tools will help broaden understanding of vestibular function in MS. This cross-sectional study's goal was to complete a robust battery of vestibular-ocular reflex (VOR), dynamic visual acuity (DVA), subjective visual vertical (SVV), and cervical and ocular vestibular-evoked myogenic potential (c/oVEMP) tests in people with and without MS.
METHODS: Forty people with relapsing-remitting MS (Expanded Disability Status Scale [EDSS] ≤6.5) and 20 controls completed the vestibular testing battery. Results were compared between groups and correlations with EDSS scores were calculated.
RESULTS: People with MS were less able to visually cancel their VOR and showed a larger variance in response on SVV. EDSS significantly correlated with VOR cancellation, SVV variance, and DVA lines lost; linear regression showed that VOR cancellation and SVV variance significantly predicted EDSS.
DISCUSSION AND CONCLUSION: Vestibular functions requiring central integration of vestibular information, but not reflexive vestibular functions like VEMP, were impaired in people with MS and correlated with EDSS, suggesting that clinical evaluation of functions requiring central integration best evaluates MS-related vestibular dysfunction. Measures assessing central vestibular integration and not vestibular reflexes may be more sensitive to detecting vestibular deficits in people with mild to moderate MS.
PMID: 33867456

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September 10, 2021

Wallerius, K., Collins, S., Forsthoefel, M., & Kim, H. J. (2021). **Increased Radiosurgery Toxicity Associated With Treatment of Vestibular Schwannoma in Multiple Sclerosis.** Otology & Neurotology, 42(4), e489–e494. https://doi.org/10.1097/MAO.0000000000002977

OBJECTIVE: Explore the risk of radiation-induced neurotoxicity in patients with multiple sclerosis (MS) treated with stereotactic radiosurgery (SRS) and better understand the pathophysiology of radiation-induced injury in the central nervous system (CNS).
PATIENTS/INTERVENTION: We present the clinical course and magnetic resonance imaging (MRI) findings of a 52-year-old woman with a history of relapsing remitting MS, who developed radiation-induced neurotoxicity following CyberKnife SRS (25 Gy in five fractions) for a left-sided vestibular schwannoma (VS).
MAIN OUTCOME MEASURE: Risk of radiation-induced damage following SRS to the CNS, including radiation type and dose, toxicity, and time to symptom onset, in patients with MS.
RESULTS: Our patient developed increased imbalance (grade 2 toxicity) 3 months following CyberKnife SRS. Brain MRI showed new fluid-attenuated inversion recovery (FLAIR) hyperintensity in the pons and cerebellum. Neurotoxicity from SRS is rare. However, our literature review showed that 19 patients with MS who underwent intracranial radiation therapy sustained radiation-induced toxicity. The potential mechanisms for increased toxicity in MS could be due to a combination of demyelination, inflammatory, and/or vascular changes. Efficacy of treatments including steroids, bevacizumab, and hyperbaric oxygen therapy is currently unknown.
CONCLUSION: Treatment options of SRS and surgery for VS should be carefully considered as patients with known MS may be at increased risk for radiation-induced damage following SRS to the CNS. Thoughtful radiosurgical planning and dosing accounting for this inherent risk is essential for managing patients with MS and VS
PMID: 33351559

September 16, 2021

Marsden, J., Pavlou, M., Dennett, R., Gibbon, A., Knight-Lozano, R., Jeu, L., Flavell, C., Freeman, J., Bamiou, D. E., Harris, C., Hawton, A., Goodwin, E., Jones, B., & Creanor, S. (2020). **Vestibular rehabilitation in multiple sclerosis: study protocol for a randomised controlled trial and cost-effectiveness analysis comparing customised with booklet based vestibular rehabilitation for vestibulopathy and a 12 month observational cohort study of the symptom reduction and recurrence rate following treatment for benign paroxysmal positional vertigo.** BMC Neurology, 20(1), N.PAG. https://doi.org/10.1186/s12883-020-01983-y

BACKGROUND: Symptoms arising from vestibular system dysfunction are observed in 49-59% of people with Multiple Sclerosis (MS). Symptoms may include vertigo, dizziness and/or imbalance. These impact on functional ability, contribute to falls and significant health and social care costs. In people with MS, vestibular dysfunction can be due to peripheral pathology that may include Benign Paroxysmal

Positional Vertigo (BPPV), as well as central or combined pathology. Vestibular symptoms may be treated with vestibular rehabilitation (VR), and with repositioning manoeuvres in the case of BPPV. However, there is a paucity of evidence about the rate and degree of symptom recovery with VR for people with MS and vestibulopathy. In addition, given the multiplicity of symptoms and underpinning vestibular pathologies often seen in people with MS, a customised VR approach may be more clinically appropriate and cost effective than generic booklet-based approaches. Likewise, BPPV should be identified and treated appropriately.
METHODS/ DESIGN: People with MS and symptoms of vertigo, dizziness and/or imbalance will be screened for central and/or peripheral vestibulopathy and/or BPPV. Following consent, people with BPPV will be treated with re-positioning manoeuvres over 1-3 sessions and followed up at 6 and 12 months to assess for any re-occurrence of BPPV. People with central and/or peripheral vestibulopathy will be entered into a randomised controlled trial (RCT). Trial participants will be randomly allocated (1:1) to either a 12-week generic booklet-based home programme with telephone support or a 12-week VR programme consisting of customised treatment including 12 face-to-face sessions and a home exercise programme. Customised or booklet-based interventions will start 2 weeks after randomisation and all trial participants will be followed up 14 and 26 weeks from randomisation. The primary clinical outcome is the Dizziness Handicap Inventory at 26 weeks and the primary economic endpoint is quality-adjusted life-years. A range of secondary outcomes associated with vestibular function will be used.
DISCUSSION: If customised VR is demonstrated to be clinically and cost-effective compared to generic booklet-based VR this will inform practice guidelines and the development of training packages for therapists in the diagnosis and treatment of vestibulopathy in people with MS.
PMID: 33243182
Link to Free Article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7694922/

September 30, 2021
Cochrane, G. D., Christy, J. B., & Motl, R. W. (2021). **Central Vestibular Functions Correlate with Fatigue and Walking Capacity in People with Multiple Sclerosis.** Physical Therapy.
https://doi.org/10.1093/ptj/pzab168

OBJECTIVE: Imbalance and fatigue are among the most common and disabling symptoms of multiple sclerosis (MS). Vestibular rehabilitation studies demonstrate not only improvements in balance but fatigue also, suggesting a relationship between central vestibular integration and fatigue. The objective of this study was to determine whether the relationship between balance and fatigue in people with MS is seen between other measures of central vestibular integration and fatigue and to understand how central vestibular integration measures interrelate.
METHODS: This cross-sectional study consisted of 40 people with MS (ages of 27-55 years, Expanded Disability Severity Scale score of 1.0-6.5) who completed vestibular ocular reflex testing, subjective visual vertical testing, static posturography, dynamic gait, 2 self-report fatigue surveys, and a 6-Minute

Walk Test to assess walking capacity/physical fatigue was completed. Spearman correlations were calculated between variables.
Results: Measures of central vestibular integration were significantly correlated with measures of fatigue and walking capacity and with each other. The correlations between physical fatigue and central vestibular functions were larger than self-reported fatigue correlations with central vestibular functions.
CONCLUSION: The relationship between balance and fatigue extends to other measures requiring central vestibular integration, suggesting a deficit in central vestibular processing in people with MS. These measures may compliment balance assessment as outcome measures for vestibular rehabilitation in people with MS. Fatigue measures should be included in vestibular rehabilitation as secondary outcomes.
IMPACT: Correlations between central vestibular integration and fatigue in people with MS suggest that future studies of vestibular rehabilitation should include fatigue as a secondary outcome measure as vestibular function and fatigue may share similar a similar etiology in people with MS.
PMID: 34174079

October

We apologize for the pause in recent Abstracts. This was due to an error with the group we use to publish these, and it is now corrected. The original topic that was planned for October will now be November's topic. The Abstract below was originally sent the first week of October but will be repeated today. The following weeks will be all new abstracts on concussion. Thank you for your ongoing support of Abstract of the Week!

November Topic: Concussion

November 1, 2021
Mikolic A, Oude Groeniger J, Zeldovich M, Wilson L, Roeters van Lennep JE, van Klaveren D, Polinder S. **Explaining outcome differences between men and women following mild traumatic brain injury.** J Neurotrauma. 2021 Oct 7. doi: 10.1089/neu.2021.0116. Epub ahead of print. PMID: 34617454.

Men and women differ in outcomes following mild traumatic brain injury (TBI). In the CENTER-TBI study, we previously found that women had worse 6-month functional outcome (Glasgow Outcome Score Extended (GOSE)), health-related quality of life (HRQoL), and mental health following mild TBI. The aim of this study was to investigate whether those differences were mediated by psychiatric history, gender-related sociodemographic variables, or by care pathways. We analyzed sex/gender differences in 6-month GOSE, generic and TBI-specific HRQoL, post-concussion and mental health symptoms using three sets of mediators: psychiatric history, sociodemographic variables (living alone, living with children, education and employment status/job category), and care-pathways (referral to study hospital and

discharge destination after Emergency Room); while controlling for a substantial number of potential confounders (pre-injury health, and injury-related characteristics). We included 1842 men and 1022 women (16+) with a Glasgow Coma Score 13-15, amongst whom 83% had GOSE available and about 60% other 6-month outcomes. We used natural effects models to decompose the total effect of sex/gender on the outcomes into indirect effects that passed through the specified mediators, and the remaining direct effects. In our study population, women had worse outcomes and these were only partly explained by psychiatric history, and not considerably explained by sociodemographic variables nor by care pathways. Other factors than differences in specified variables seem to underlie observed differences between men and women in outcomes after mild TBI. Future studies should explore more aspects of gender roles and identity, and biological factors underpinning sex and gender differences in TBI outcomes.
PMID: 34617454

November 8, 2021
Anthony P Kontos 1 2, Shawn R Eagle 1 2, Gregory Marchetti 3 2. **Discriminative Validity of Vestibular Ocular Motor Screening in Identifying Concussion Among Collegiate Athletes: A National Collegiate Athletic Association-Department of Defense Concussion Assessment, Research, and Education Consortium Study.** Am J Sports Med. 2021 Jul;49(8):2211-2217.

Background: Vestibular and ocular motor screening tools, such as the Vestibular/Ocular Motor Screening (VOMS), are recognized as important components of a multifaceted evaluation of sport-related concussion. Previous research has supported the predictive utility of the VOMS in identifying concussion, but researchers have yet to examine the predictive utility of the VOMS among collegiate athletes in the first few days after injury.
Purpose: To determine the discriminative validity of individual VOMS item scores and an overall VOMS score for identifying collegiate athletes with an acute sport-related concussion (≤72 hours) from healthy controls matched by age, sex, and concussion history.
Study design: Case-control study; Level of evidence, 3.

Methods: Participants (N = 570) aged 17 to 25 years were included from 8 institutions of the National Collegiate Athletic Association-Department of Defense CARE Consortium (Concussion Assessment, Research, and Education): 285 athletes who were concussed (per current consensus guidelines) and 285 healthy controls matched by age, sex, and concussion history. Participants completed the VOMS within 3 days of injury (concussion) or during preseason (ie, baseline; control). Symptoms are totaled for each VOMS item for an item score (maximum, 40) and totaled across items for an overall score (maximum, 280), and distance (centimeters) for near point of convergence (NPC) is averaged across 3 trials. Receiver operating characteristic analysis of the area under the curve (AUC) was performed on cutoff scores using Youden index (J) for each VOMS item, overall VOMS score, and NPC distance average. A logistic regression was conducted to identify which VOMS scores identified concussed status.

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Results: A symptom score ≥1 on each VOMS item and horizontal vestibular/ocular reflex ≥2 significantly discriminated concussion from control (AUC, 0.89-0.90). NPC distance did not significantly identify concussion from control (AUC, 0.51). The VOMS overall score had the highest accuracy (AUC, 0.91) for identifying sport-related concussion from control. Among the individual items, vertical saccades ≥1 and horizontal vestibular/ocular reflex ≥2 best discriminated concussion from control.

Conclusion: The findings indicate that individual VOMS items and overall VOMS scores are useful in identifying concussion in collegiate athletes within 3 days of injury. Clinicians can use the cutoffs from this study to help identify concussion in collegiate athletes.
PMID: 33979240

November 17, 2021
Santo AL, Race ML, Teel EF. **Near Point of Convergence Deficits and Treatment Following Concussion: A Systematic Review.** J Sport Rehabil. 2020 Nov 1;29(8):1179-1193. doi: 10.1123/jsr.2019-0428. Epub 2020 Mar 4.

Context: Convergence dysfunction following concussion is common. Near point of convergence (NPC) is a quick and easy assessment that may detect oculomotor dysfunction such as convergence insufficiency (CI), but NPC measurements are rarely reported. Convergence dysfunction is treatable in otherwise healthy patients; the effectiveness of oculomotor therapy following concussion is unclear.

Objectives: The purpose of this article was to systematically review the literature and answer the following clinical questions: (1) Is performance on NPC negatively affected in patients diagnosed with a concussion compared with pre-injury levels or healthy controls? (2) In patients diagnosed with concussion, what is the effect of oculomotor/vision therapy on NPC break measurements?

Evidence acquisition: The search was conducted in CINAHL, SPORTDiscus, MEDLINE, and PubMed using terms related to concussion, mild traumatic brain injury, convergence, vision, and rehabilitation. Literature considered for review included original research publications that collected measures of NPC break in concussion patients, with a pretest-posttest comparison or comparison with a healthy control group. A literature review was completed; 242 relevant articles were reviewed, with 18 articles meeting criteria for inclusion in the review.

Evidence synthesis: Articles were categorized according to the clinical question they addressed. The patient or participant sample (number, sex, age, and health status), study design, instrumentation, or intervention used, and main results were extracted from each article.

Conclusions: The authors' main findings suggest that there is a moderate level of evidence that patients have impaired NPC up to several months postconcussion, and a low level of evidence that impairments can be successfully treated with oculomotor therapy. These findings should be cautiously evaluated; the

studies are limited by weak/moderate quality, small sample sizes, varied methodology, and nonrandomized treatment groups. Future research should explore factors affecting convergence postconcussion and include randomized, controlled studies to determine if performing vision therapy improves visual measures and promotes recovery.
PMID: 32131046

November 24, 2021
Womble MN, McAllister-Deitrick J, Marchetti GF, Reynolds E, Collins MW, Elbin RJ, Kontos AP**. Risk Factors for Vestibular and Oculomotor Outcomes After Sport-Related Concussion.** Clin J Sport Med. 2021 Jul 1;31(4):e193-e199. doi: 10.1097/JSM.0000000000000761.

Objective: To investigate the association between risk factors and vestibular-oculomotor outcomes after sport-related concussion (SRC).

Study design: Cross-sectional study of patients seen 5.7 ± 5.4 days (range 0-30 days) after injury.

Setting: Specialty clinic.

Participants: Eighty-five athletes (50 male athletes and 35 female athletes) aged 14.1 ± 2.8 years (range 9-24 years) seeking clinical care for SRC.

Interventions: Participants completed a clinical interview, history questionnaire, symptom inventory, and vestibular/ocularmotor screening (VOMS). Chi-square tests with odds ratios and diagnostic accuracy were used to examine the association between risk factors and VOMS outcomes.

Main outcome measures: The VOMS.

Results: Female sex ($\chi2 = 4.9$, $P = 0.03$), on-field dizziness ($\chi2 = 7.1$, $P = 0.008$), fogginess ($\chi2 = 10.3$, $P = 0.001$), and post-traumatic migraine (PTM) symptoms including headache ($\chi2 = 16.7$, $P = 0.001$), nausea ($\chi2 = 10.9$, $P = 0.001$), light sensitivity ($\chi2 = 14.9$, $P = 0.001$), and noise sensitivity ($\chi2 = 8.7$, $P = 0.003$) were associated with presence of one or more postconcussion VOMS score above clinical cutoff. On-field dizziness ($\chi2 = 3.8$, $P = 0.05$), fogginess ($\chi2 = 7.9$, $P = 0.005$), and PTM-like symptoms including nausea ($\chi2 = 9.0$, $P = 0.003$) and noise sensitivity ($\chi2 = 7.2$, $P = 0.007$) were associated with obtaining a postconcussion near-point convergence (NPC) distance cutoff >5 cm. The likelihood ratios were 5.93 and 5.14 for VOMS symptoms and NPC distance, respectively.

Conclusions: Female sex, on-field dizziness, fogginess, and PTM symptoms were predictive of experiencing vestibular-oculomotor symptoms/impairment after SRC.
PMID: 31219931

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December Topic: Postural Threat

December 2, 2021

Lim, S. B., Cleworth, T. W., Horslen, B. C., Blouin, J. S., Inglis, J. T., & Carpenter, M. G. (2017). **Postural threat influences vestibular-evoked muscular responses.** Journal of neurophysiology, 117(2), 604–611. https://doi.org/10.1152/jn.00712.2016

Standing balance is significantly influenced by postural threat. While this effect has been well established, the underlying mechanisms of the effect are less understood. The involvement of the vestibular system is under current debate, and recent studies that investigated the effects of height-induced postural threat on vestibular-evoked responses provide conflicting results based on kinetic (Horslen BC, Dakin CJ, Inglis JT, Blouin JS, Carpenter MG. J Physiol 592: 3671-3685, 2014) and kinematic (Osler CJ, Tersteeg MC, Reynolds RF, Loram ID. Eur J Neurosci 38: 3239-3247, 2013) data. We examined the effect of threat of perturbation, a different form of postural threat, on coupling (cross-correlation, coherence, and gain) of the vestibulo-muscular relationship in 25 participants who maintained standing balance. In the "No-Threat" conditions, participants stood quietly on a stable surface. In the "Threat" condition, participants' balance was threatened with unpredictable mediolateral support surface tilts. Quiet standing immediately before the surface tilts was compared to an equivalent time from the No-Threat conditions. Surface EMG was recorded from bilateral trunk, hip, and leg muscles. Hip and leg muscles exhibited significant increases in peak cross-correlation amplitudes, coherence, and gain (1.23-2.66×) in the Threat condition compared with No-Threat conditions, and significant correlations were observed between threat-related changes in physiological arousal and medium-latency peak cross-correlation amplitude in medial gastrocnemius (r = 0.408) muscles. These findings show a clear threat effect on vestibular-evoked responses in muscles in the lower body, with less robust effects of threat on trunk muscles. Combined with previous work, the present results can provide insight into observed changes during balance control in threatening situations.

New & noteworthy: This is the first study to show increases in vestibular-evoked responses of the lower body muscles under conditions of increased threat of postural perturbation. While robust findings were observed in hip and leg muscles, less consistent results were found in muscles of the trunk. The present findings provide further support in the ongoing debate for arguments that vestibular-evoked balance responses are influenced by fear and anxiety and explain previous threat-related changes in balance.
PMID: 31219931
Link to Free Article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5288487/

December 10, 2021

Ellmers TJ, Kal EC, Young WR. **Consciously processing balance leads to distorted perceptions of instability in older adults.** J Neurol. 2021 Apr;268(4):1374-1384. doi: 10.1007/s00415-020-10288-6. Epub 2020 Nov 3.

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Background: Persistent dizziness without a clear cause is common in older adults. We explored whether an anxiety-driven preoccupation with consciously processing balance may underpin the distorted perceptions of unsteadiness that characterises 'unexplained' dizziness in older adults.

Methods: We experimentally induced anxiety about losing one's balance (through a postural threat manipulation) in a cohort of asymptomatic older adults and evaluated associated changes in perceived stability, conscious movement processing and postural control. These outcomes were also assessed when performing a distracting cognitive task designed to prevent anxiety-related conscious movement processing, in addition to during baseline conditions (ground level).

Results: Despite a lack of increase in postural sway amplitude ($p = 0.316$), participants reported reductions in perceived stability during postural threat compared to baseline ($p < 0.001$). A multiple linear regression revealed that anxiety-related conscious movement processing independently predicted perceptions of instability during this condition ($p = 0.006$). These changes were accompanied by alterations in postural control previously associated with functional dizziness, namely high-frequency postural sway and disrupted interaction between open- and closed-loop postural control ($ps < 0.014$). While the distraction task successfully reduced conscious processing ($p = 0.012$), leading to greater perceived stability ($p = 0.010$), further increases in both postural sway frequency ($p = 0.002$) and dominance of closed-loop control ($p = 0.029$) were observed.

Conclusion: These findings implicate the role of conscious movement processing in the formation of distorted perceptions of unsteadiness, suggesting that such perceptions may be modifiable by reducing an over-reliance on conscious processes to regulate balance.
PMID: 33141249
Link to Free Article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7990754/

December 16, 2021
Cleworth TW, Adkin AL, Allum JHJ, Inglis JT, Chua R, Carpenter MG. **Postural Threat Modulates Perceptions of Balance-Related Movement During Support Surface Rotations.** Neuroscience. 2019 Apr 15;404:413-422. doi: 10.1016/j.neuroscience.2019.02.011. Epub 2019 Feb 18.

Postural threat decreases center of pressure displacements yet increases the magnitude of movement-related conscious sway perception during quiet standing. It is unknown how these changes influence perception of whole body movement during dynamic stance. The aim of this study was to examine how postural threat influences whole-body movements and conscious perception of these movements during continuous pseudo-random support surface perturbations to stance. Sixteen healthy young adults stood on a moveable platform with their eyes closed for 7 min in a low threat (1.1 m above ground, away from edge) then high threat (3.2 m above ground, near edge) condition. Continuous pseudorandom roll platform rotations (± 4.5°, < 0.5 Hz) evoked large amplitude sway in the medio-lateral (ML) direction. Participants were asked to remain upright and avoid a fall at all times while

tracking their ML body movements using a hand-held rotary encoder. Kinematic data was recorded using three markers placed on the upper trunk. Questionnaires assessed anxiety, fear and confidence. Electrodermal activity (EDA) was recorded as an indicator of arousal. Height-induced threat increased fear, anxiety and EDA, and decreased confidence. Trunk sway amplitude remained constant, while tracked movement amplitude increased at height. The gain for perceived to trunk movement was significantly increased at height across frequencies. Threat-related increases in sensitivity of sensory systems related to postural control and changes in cognitive and attention processes may lead to misperceptions of actual movement amplitudes, which may be important when examining increased fall risk in those with a fear of falling.
PMID: 30790669

December 29, 2021
Cleworth, T. W., Allum, J., Luu, M. J., Lea, J., Westerberg, B. W., & Carpenter, M. G. (2020). **The Effect of Unilateral Vestibular Loss on Standing Balance During Postural Threat.** Otology & neurotology : official publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology, 41(7), e945–e951. https://doi.org/10.1097/MAO.0000000000002485

Objective: Vestibular deficit patients have an increased fall risk and fear of falling. Postural threat, known to increase balance-related fear and anxiety, influences vestibular gains during quiet standing in young healthy adults. The current study examined whether there is a similar relationship for peripheral unilateral vestibular loss (UVL) patients in comparison to age-matched healthy controls (HC).

Setting: University laboratory.

Study design: Prospective laboratory study.

Patients and controls: Eleven UVL patients, nine with vestibular neurectomy. Eleven aged-matched HCs.

Main outcome measures: Subjects stood on a hydraulic lift placed at two heights: low (0.8 m, away from the edge) and high (3.2 m, at the edge). Amplitude (root mean square), mean power frequency (MPF), and mean position were analyzed for center of foot pressure (COP) and 90% ranges for angle amplitude and velocity for trunk sway.
Results: Group interactions were strongest for anterior-posterior (AP) COP and trunk pitch angle. AP lean away from the edge was greater in HCs than UVLs. HCs, but not UVLs had a decrease in root mean square AP COP with height. Trunk pitch sway was changed similarly. Both groups had increased trunk pitch velocity at height. Changes with height were less for roll: MPF of lateral COP increased with height for UVLs with no changes for HCs, and trunk roll amplitude decreased for both groups.

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Conclusions: This report provides evidence for a differential effect of height induced postural threat on balance control between UVLs and HCs presumably due to the reduced vestibular-spinal gain in UVL subjects.
PMID: 32658112