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ABSTRACT

Purpose: This case report presents evidence-based physical therapy assessments and interventions for a patient with unilateral vestibular hypofunction (UVH). UVH is the result of peripheral vestibular dysfunction in the inner ear. ***Case Description***: The patient was a 48-year-old male with symptoms of dizziness, cephalalgia, and cervicalgia. The examination and treatment were focused on impaired cervical proprioception, which is a vital component of balance training in addition to visual, vestibular, and somatosensory re-education for patients with dizziness. Toward the end of the physical therapy episode of care, the patient was medically diagnosed with Chiari malformation, a congenital cerebellar tonsillar herniation. ***Outcomes***: The patient made significant strides on the Dizziness Handicap Inventory, Ten Meter Walk Test, Single Leg Stance, Balance Error Scoring System, Fukuda Stepping Test, Cervical Joint Position Error Sense Test, Convergence Distance, Global Rate of Change, and cervical range of motion assessments. The patient did not demonstrate comparable improvements on the Dynamic Visual Acuity Test. ***Conclusion***: This case report demonstrates a physical therapy program for a patient with peripheral UVH-related symptoms. This approach may also be applicable for patients with the central cause of dizziness such as Chiari malformation. Future directions for research and clinical practice are also suggested in this report.

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Vertigo; unilateral vestibular hypofunction; Chiari malformation; joint position sense error

Introduction

Dizziness is a common and nebulous diagnosis often assessed and treated by physical therapists. Dizziness is typically described as a sensation of lightheadedness, unsteadiness, or faintness, whereas vertigo is specifically described as a sensation of rotatory movement of either oneself or one's environment. Vertigo is a vestibular dysfunction with a prevalence of 12% in the dizzy population (Ali et al. 2016; Teggi et al. 2016). Literature suggests that dizziness and vertigo affect 15–35% of the American population, with 25% of these cases being primarily vertiginous (Ali et al. 2016; Kerber et al. 2017; Neuhauser 2016). One point-prevalence study reported that in the dizzy population, 35% of people reported headaches, 13% reported positional exacerbation, and 12% reported hearing dysfunction in addition to unsteadiness (Teggi et al. 2016). Furthermore, dizzy patients with headaches reported greater rates of relapse and positional exacerbation (Teggi et al. 2016). Patients with headaches and vertigo can present with cervical range of motion (ROM) restrictions and disturbed sleep due to cervicalgia (Furman and Whitney 2000). In addition, patients with dizziness may also suffer from a host of concurrent and debilitating symptoms including headaches, positional exacerbations, hearing dysfunction, cervicalgia, cervical ROM deficits, and disturbed sleep. In this case report, the patient presented with all of the aforementioned deficits at his physical therapy initial evaluation.

Dizziness may be triggered by a plethora of physiologic causes including vestibular, neurologic, cardiovascular, pulmonary, and/or psychological dysfunction. One example of a vestibular cause of dizziness is unilateral vestibular hypofunction (UVH), a peripheral inner ear dysfunction. UVH may present as vestibular neuronitis or labrynthitis when caused by bacterial or viral inner ear infections. Other causes include perilymphatic fistulas, acoustic neuromas, aging, pharmacologic toxicity, or malignancy. UVH produces symptoms of dizziness, nausea, oculomotor disturbances, and gait deviations with involvement of the

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vestibular nerve and tinnitus with the additional involvement of the cochlear nerve (Herdman and Clendaniel 2014). The patient presented in this case report was diagnosed with an acute 81% unilateral vestibular function loss secondary to an inner ear infection via videonystagmography testing.

In addition to peripheral causes, dizziness may be centrally caused by migraine, head trauma, concussion, vertebrobasilar insufficiency, brainstem dysfunction, and cerebellar dysfunction (Furman and Whitney 2000). Vertigo secondary to cerebellar dysfunction accompanies deficits in the vestibulo-ocular system, postural control system, visual-vestibular integration, rapid head movement, and static and dynamic balance (Furman and Whitney 2000). The patient presented in this case report was medically diagnosed with Chiari malformation toward the end of physical therapy episode of care. Chiari malformation is one example of such a cerebellar dysfunction. These congenital (1/1280 births) cerebellar tonsillar herniations are typically diagnosed via imaging (Meadows et al. 2000). Clinical symptoms of Chiari malformation include central vertigo, cephalalgia, cervicalgia, abnormal gait, coordination impairments, nausea, tinnitus, and impaired concentration. While these herniations are congenital, patients are typically asymptomatic until adulthood. Currently, medications and surgery are the most common means to medically manageable Chiari malformation (Langridge et al. 2017; Lu et al. 2017; Merello et al. 2017).

Cervical proprioception is an important aspect of a cohesive and centrally stable balance system, while vision, vestibular, and somatosensory systems play integral roles in improving balance deficits in dizziness treatment (Kristjansson and Treleaven 2009). Cervicocephalic position sense is a collaboration of peripheral mechanoreceptors, cervical proprioceptors, visual input, and vestibular input – combining aspects of both peripheral and central balance systems. Cervical proprioception is not only important for postural orientation and equilibrium mechanisms but also plays an integral role in maintaining healthy vestibulo-ocular system function and head orientation. Cervicalgia, which often accompanies central vertigo as described above, may impair cervical proprioception via the following mechanisms: (1) local inflammation may chemically alter muscle spindle sensitivity and/or induce reflexive joint inhibition specifically at the cervical facet joints; (2) neck musculature atrophy and/or fatty infiltrations due to prolonged patient guarding may diminish cervical proprioceptive acuity; (3) prolonged cervicalgia may negatively impact cortical somatotopic representation of the cervical spine (De Vries et al. 2015; Elliott et al. 2006; Flor 2003; Le Pera et al. 2001; McPartland et al. 1997; Sterling et al. 2003; Thunberg et al. 2001; Windhorst and Kokkoroyiannis 1992). Further, cervical proprioception is significantly reduced in those with both traumatic and non-traumatic cervicalgia as compared to healthy individuals regardless of length or intensity of neck pain (De Vries et al. 2015). In fact, moderate to high Neck Disability Index scores are correlated to chronically poor joint position sense error (JPSE), the quantitative measure of cervical proprioception (De Vries et al. 2015; Sterling et al. 2003). Therefore, cervical proprioception is a necessary assessment for patients suffering from vertigo, impaired balance, and cervicalgia.

Regardless of peripheral or central origins of dizziness, and especially in patients with cervicalgia, JPSE is a key component of dizziness assessment. The Cervical Joint Position Sense Error Test (CJPSET) is a clinical measure of head and neck repositioning error. CJPSET scores are highly predictive of balance dysfunction (Treleaven et al. 2006). The literature supports a multimodal approach to training cervical proprioception deficits with treatments including: cervical neuromuscular control training (i.e. tracing patterns on wall with laser mounted to head); oculomotor training (i.e. moving eyes quickly between two targets, viewing stationary object with horizontal and/or vertical head turns); balance training (i.e. stance or gait on varied compliant surfaces with eyes open or eyes closed); craniocervical flexion training, manual therapy, and cervical ROM exercises (Clark et al. 2015; Jull et al. 2007; Kristjansson and Treleaven 2009; Treleaven 2008a,2008b).

While peripheral causes of vertigo are relatively well-studied, the body of available literature regarding central vertigo rehabilitation is comparatively less robust. This case report presents the evidence-based physical therapy examination and management, with an additional focus on cervical proprioception, on a patient with multiple symptoms secondary to the original diagnosis of UVH. However, during the physical therapy episode of care, the patient was also found to have a Chiari malformation. Since Chiari malformations are typically congenital, it would be reasonable to suggest that the patient's symptoms might be, at the same time, caused by this cerebellar dysfunction. Therefore, the physical therapy assessment and interventions presented in this report may also be applicable to future patients with Chiari malformation.

Case description

Patient history

The patient was a 48-year-old male referred to physical therapy for acute dizziness over five days, with

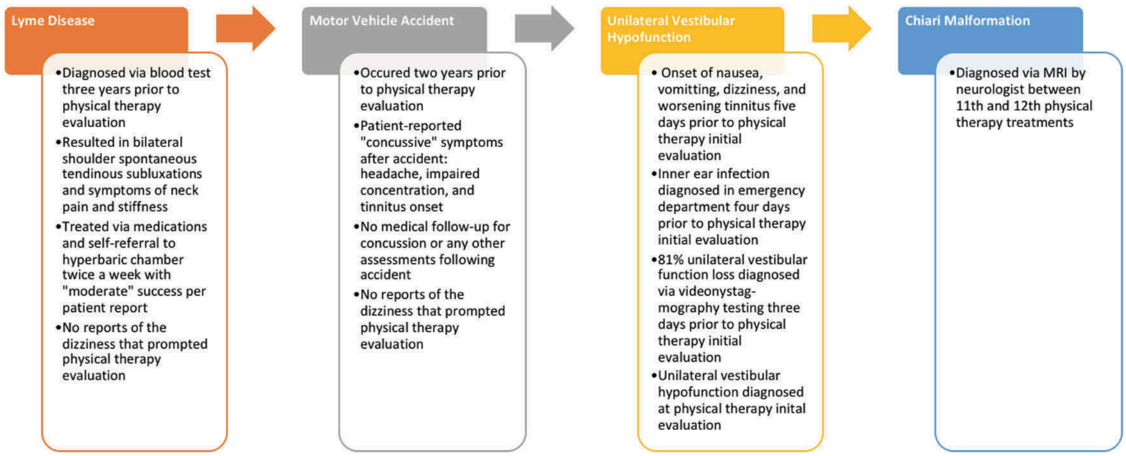

Figure 1. Patient medical history timeline.

additional complaints of constant headache, neck pain and stiffness, impaired concentration, and tinnitus over the past two to three years. The patient described that his "spinning" symptom intensified with visual input, turning his head up or down, and sit-to-stand transfers, and improved with quiet rest. The patient was medically diagnosed with Lyme disease via a blood test three years prior to this physical therapy initial evaluation, for which he utilized a hyperbaric chamber twice a week with moderate success. Per patient report, he received a left rotator cuff repair seven years prior and a right bicep tenodesis procedure one year prior to initial evaluation following spontaneous tendinous subluxations secondary to Lyme disease. Two years prior to this initial evaluation, the patient was involved in a motor vehicle accident with reported but untreated concussive symptoms. The patient denied a history of personal or familial migraines. The patient's medical history timeline is summarized in Figure 1.

The patient actively participated in leisure and social activities including running, yard work, and playing with his children. During a 40-h work week as an industrial plant control systems specialist, the patient routinely intently concentrated on problem solving while turning his head throughout the day in the presence of loud noises. The patient reported that he was barbequing when he first felt symptomatic of dizziness. His symptoms worsened the following day with onset of nausea and vomiting, prompting an emergency department visit which identified a right inner ear infection. The next morning the patient participated in a videonystagmography test, confirming that 81% of his vestibular function was compromised via a hypothesized right ear infection. The patient was prescribed antibiotics, Lunesta (1 mg PRN), diazepam (5 mg PRN), and Losoma to alleviate physical and emotional symptoms.

At initial evaluation and throughout his episode of care, a neurologist and/or neuropathologist evaluation was recommended considering his complex medical history. However, the patient reported difficulty finding a doctor willing to treat him after his motor vehicle accident. Toward the end of his episode of care, the patient was able to visit a neurologist who diagnosed him with a Chiari malformation via imaging between his eleventh and twelfth physical therapy visits.

Physical therapy examination

The patient was 1.85 m tall and weighed 102.1 kg (BMI 29.7). He reported a "normal to high" blood pressure with an average resting heart rate of 70 beats per minute. On skilled observation, guarded and stiff cervical ROM and avoidance of gaze toward bright lights for fear of aggravating headache were noted. All examination findings are detailed in Table 1.

The patient reported 5/10 present dizziness, with symptoms being 5/10 at best and 8/10 at worst. He scored an 84/100 on the Dizziness Handicap Inventory (DHI, physical: 28, emotional 26, functional: 30; Figure 2). During vestibular assessment, positional changes to and from sitting to side-lying toward the left and right and sitting to standing failed to elicit symptoms. Spontaneous nystagmus, gaze-holding nystagmus, smooth pursuit, ocular ROM, and saccades testing were conducted in room light without use of visual aids and deemed normal bilaterally. The patient's convergence distance was 25.4 cm. His right head thrust test was positive and produced symptoms of lightheadedness. The patient demonstrated a difference of four lines between static and dynamic portions of the Dynamic Visual Acuity Test (DVAT) at a speed of 2 Hz. The patient was unable to maintain single leg stance with eyes closed on a firm surface for more than one second on each leg. Table 2

Table 1. Outcome measures per assessment.

Components	Initial evaluation	First re-evaluation	Second re-evaluation
Numeric Pain Rating Scale (out of 10)	• Current Pain: 5 • Best Pain: 5 • Worst Pain: 8	• Current Pain: 0 • Best Pain: 0 • Worst Pain: 2	• Current pain: 8 • Best pain: 7 • Worst pain: 8
Dizziness Handicap Inventory	• Physical: 28, Emotional: 26, Functional: 30 • Total Score: 84	• Physical: 6, Emotional: 8, Functional: 6 • Total Score: 20	• Physical: 6, Emotional: 8, Functional: 6 • Total Score: 20
Global Rate of Change	• Not tested	• 13	• 14
Positional testing	• Sit to Side-lying: L/down, L/up, R/down, R/up absent. • Sit to Stand: absent	• VBI testing negative	• Not tested
VOR testing (in room light without glasses or contacts)	• Spontaneous nystagmus, gaze-holding nystagmus, smooth pursuit, ocular ROM, saccades: normal • Convergence: 25 cm • Right head thrust test: abnormal, also produced lightheadedness • Left head thrust test: normal	• Convergence: normal, 0 cm from nose. • Head thrust test to right: abnormal	• Head thrust test: negative.
Dynamic Visual Acuity Test	• Static: line 7 • Dynamic: line 3	• Static: line 8 • Dynamic: line 4	• Static: line 10 • Dynamic: line 6
Static and Dynamic Balance	• Bilateral SLS (eyes closed, firm surface) = unable	• Bilateral SLS (eyes closed, firm surface) = 30 sec • BESS Test = 21 errors • FUKUDA Balance Assessment = 110º, 53.5 cm over 100 steps.	• BESS Test = 6 errors • FUKUDA Balance Assessment = 40º, 225 cm over 100 steps total.
Gait/Locomotion	• Not tested	• Ten meter walk test = 5 sec	• Ten meter walk test = 3 sec
Cervical Spine Testing	• Distraction, Spurling's, and ROM = normal (based on gross observation).	• Range of Motion – Flexion, extension, R rotation: WFL – R side-bend: 45 – L side-bend: 40 – L rotation: 60 • Accessory Motions – R side-glide of lower cervical spine – hypomobile – Posterior glide of OA joint – hypomobile • Cervical Joint Error Position Sense Test – R rot: 2/5 correct. – L rot: 1/5 correct. – Extension: 1/5 correct.	• Range of Motion – Flexion, extension, R rotation: WFL – R side-bend: 60 – L side-bend: 58 – L rotation: 50 • Accessory Motions: – R side-glide and R PA unilateral glide hypomobile – Posterior glide of OA and traction normal. • Cervical Joint Error Position Sense Test: – R rot, L rot, and extension: 5/5 correct.

Abbreviations: IE = Initial Evaluation. Tx = Treatment Session. EO, EC = Eyes Open, Eyes Closed. HEP = Home Exercise Program. L/R = left/right. WBOS = wide base of support. Pt. = patient. w/ = with. min = minute. sec = seconds. ROM = range of motion. SLS = single leg stance. LD = Lyme Disease. EC/EO = eyes closed/open. UT = upper trapezius. VBI = vertebrobasilar insufficiency. WFL = within functional limits.

includes psychometrics on all subjective and objective outcome assessments.

Physical therapy diagnosis and prognosis

The findings of the physical therapy examination suggested UVH with vestibulo-ocular reflex (VOR) dysfunction, DHI deficits, convergence deficits, head thrust abnormalities, dynamic visual acuity deficits, and balance dysfunction. The patient's primary problems included dizziness, cephalalgia, cervicalgia, and balance impairments which limited him from independent and symptom-free participation in functional, vocational, and leisure activities. Physical therapy twice per week for eight weeks was recommended (Hall et al. 2016b). Table 3 summarizes the patient-selected and therapist-selected goals for physical therapy treatment.

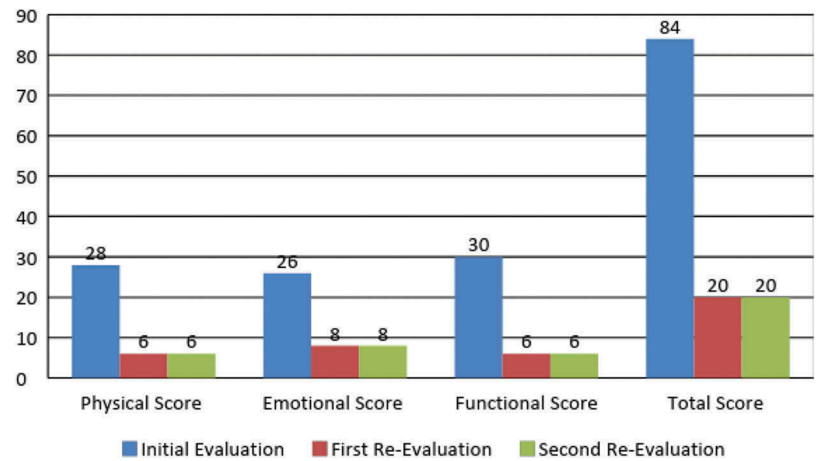

Figure 2. Dizziness handicap inventory.

Interventions

Given the patient's goals as listed in Table 3, patient and family education, cardiovascular exercise, and manual therapy were incorporated throughout the patient's episode of care. Every session incorporated patient and family education to equip involved parties with autonomy and salience over the prescribed plan of care. The patient was specifically and extensively instructed regarding the interdependence of visual, vestibular, somatosensory, and cervical proprioception components of a cohesive balance system (Hall et al. 2016a, 2016b; Kristjansson and Treleaven 2009). The patient participated in a cardiovascular warm-up each session to progress toward his personal goal of symptom-free running and benefit from endogenous pain control mechanisms (Hoffman et al. 2005). This warm-up progressed from upper body ergometer to ambulation to jogging on an incline. There is precedence for utilizing manual therapy to diminish cervicalgia, dizziness, and cervical proprioception deficits (Bialosky et al. 2009; Bracher et al. 2000; Galm et al. 1998; Gong 2013; Li and Peng 2015; Reid and Rivett 2005). As the patient exhibited each of these deficits, he received manual therapies including cervical spine distraction, mobilization, suboccipital release, and manual bilateral cervical musculature stretching.

Cervical proprioception is an often overlooked but vital component of balance training (Kristjansson and Treleaven 2009). One intervention gaining traction in the physical therapy community to improve cervical proprioception is laser training. JPSE is the primary clinical measure of cervical proprioception, and CJPSET is found to be reliable in the cervicalgia population (De Vries et al. 2015). Laser training has proven to not only effectively train cervical proprioception but is more efficacious than conventional craniocervical flexion training alone (Jull et al. 2007; Treleaven et al. 2006). Laser training has been shown to be effective for improving oculomotor tracking, cervical kinesthesia, and active joint positioning (Clark et al. 2015; Treleaven 2008a, 2008b). Thus, the patient participated in laser training paired with various challenges and positions including sitting, standing on firm and compliant surfaces in Romberg or single leg stance, cervical tracing clockwise and counterclockwise, and craniocervical flexion activities.

The patient participated in traditional vestibular adaptation and balance exercises recommended in the literature to target gait, balance, and dynamic visual acuity. These included horizontal and vertical times one and times two viewing, static balance progression from normal to Romberg to tandem stance with eyes open and closed on firm and compliant surfaces, and gait with horizontal head turns, vertical head turns, and ball tossing (Giray et al. 2009; Hall et al. 2016a, 2016b; Herdman et al. 2003; Hillier and Hollohan 2007; Morimoto et al. 2011; Schubert et al. 2008). A metronome application on the patient's cellular phone was utilized with his consent to time head movements at 1.33 Hz to start, with progression toward 2 Hz per patient tolerance. Cervical musculature strength and proprioceptive training were administered via suboccipital "yes" and "no" nods on a wall and craniocervical flexion training on a compliant surface (Jull et al. 2007; O'Riordan et al. 2014; Olson and Joder 2001). Specific therapeutic interventions and progressions are detailed in Table 4.

Outcomes

Between the initial evaluation and the first re-evaluation, the patient was treated twice a week for four weeks. Table 1 summarized details of all objective findings gathered at initial evaluation, first re-evaluation, and second

Table 2. Outcome measure psychometrics.

Category	Outcome measures	Psychometrics
Self-Reported	Dizziness Handicap Inventory	• Measure of self-perceived functional, physical, and emotional disability.[a] • Excellent test-retest reliability of the sub-scale and the total scores.[a] • Scores of 0–30 indicate mild handicap, 31–60 indicate moderate handicap, and 61–100 indicate severe handicap.[b] • The MDC for peripheral and central vestibular pathology is 17 points whereas the MCID is 18 points.[a] • Highly recommended for vestibular disorders by APTA Vestibular Taskforce VEDGE.
Objective	10 Meter Walk Test	• The 10 mWT is a gait speed assessment. • MCID is 0.1 m/s.[c] • <.4 m/s is household gait speed and >.8 m/s is community gait speed.[d] • Males aged 40–49 have a comfortable gait speed of 3.72 m/s.[d] • The APTA Vestibular Taskforce VEDGE deems this test "reasonable to use" for vestibular diagnoses.
	Single Leg Stance	• The Single Leg Stance test is a functional assessment of balance with age and gender specific norms.[e] • Males aged 40–49 have a norm of 29.7 ± 1.3 seconds with eyes open on this test.[e] • The APTA Vestibular Taskforce deems this test "reasonable to use" for vestibular diagnoses.
	Dynamic Visual Acuity Scale	• The Dynamic Visual Acuity Test is a behavioral measure of vestibulo-ocular reflex function and gaze stability.[f] • DVAT has no established MDC or MCID, it does have established norms for unilateral vestibular hypofunction.[f] • Loss of <3 lines of visual acuity during dynamic testing conditions is considered "within normal limits."[f] • Loss of 3 or more lines is suggestive of potential vestibular dysfunction.[f]
	Convergence Distance	• Normal distance = 4–6 cm from nose.[g]
	Global Rate of Change	• Test-retest reliability: ICC = 0.90 [h] • MDC = 0.45 points [h] • MCID = 2 points [h]
	Range of Motion of Cervical Spine	• MDC [i] – Flexion = 6.5 – Extension = 9.3 – Lateral flexion = 5.9 – Rotation = 5.5 • ICC for all = 0.76 to 0.97, all excellent.[i]
	BESS Test	• Healthy adults aged 40–49 = 11.88 errors.[j] • Healthy males aged 40–49 = 12.4 errors.[j]
	Fukuda Stepping Test	• Ages 40–49 norms: 71.7 ± 35 cm forward displacement, 26.7 ± 11.3 degrees rotation.[k] • MDC, angle of rotation = 23 degrees for 100 steps.[l] • MDC, angle of displacement = 16.4 degrees for 100 steps.[l] • MDC, distance of displacement = 20.4 cm for 100 steps.[l]
	Cervical Joint Position Error Test	• Mean error in healthy controls aged 19–63 = 1.3 to 4.7 degrees.[m] • Chronic cervical pain: [n] (A) ≤4.5 degrees is normal cervical proprioception (SN 86, SP 93). (B) >4.5 degrees is abnormal cervical proprioception.

[a]Jacobson and Newman 1990; [b]Whitney et al. 2004; [c]Perera et al. 2006; [d]Bohannon 1997; [e]Springer et al. 2007; [f]Longridge and Mallinson 1984; [g]Cooper et al. 2010; [h]Kamper et al. 2009; [i]Fletcher and Bandy 2008; [j]Iverson et al. 2008; [k]Arnold et al. 2017; [l]Bonanni and Newton 1998; [m]Strimpakos et al. 2006; [n]Revel et al. 1994.

re-evaluation. At the first re-evaluation, the patient reported a decrease in worst headache from 8/10 to 2/10, meeting the minimal clinically important difference (MCID) of 1.3 points on the Numeric Pain Ratings Scale (NPRS) four times over (Cleland et al. 2008). The patient's DHI score improved from 84 to 20 points (Figure 2), indicating improvement from severe to mild handicap as well as meeting both MCID and minimal detectable change (MDC) for vestibular pathology on this test (Jacobson and Newman 1990; Whitney et al. 2005, 2004). The patient's convergence distance improved from 25.4 to 0 cm, a score better than the norm of

Table 3. Physical therapy goals.

Patient-Selected Goals at Initial Evaluation	(1) Achieve independence with driving 1.5 h to and from place of work in Houston rush-hour traffic. (2) Improve balance to return to active lifestyle and outdoor running. (3) Current functional self-rating from 0 to 10, with "10" being able to function without limitation: 0 on each of these goals.
Patient-Selected Goals at Second Re-Evaluation	(1) Achieve independence with driving 1.5 h to and from place of work in Houston rush-hour traffic. *ACHIEVED* (2) Improve balance to return to active lifestyle and outdoor running. *ACHIEVED* (3) Current functional self-rating from 0 to 10, with "10" being able to function without limitation: 10 on each of these goals.
Therapist-Selected Goals at Initial Evaluation	(1) Patient has a good understanding of home exercise program for carryover from PT sessions in 2 weeks. *INITIAL* (2) Patient will reduce score on the Dizziness Handicap Inventory by 18 points from 84/100 to 66/100, demonstrating reduced fall risk status in 4 weeks. *INITIAL* (3) Patient will improve single limb stance eyes closed up to 10 s to allow patient to ambulate with decreased risk of falling in 4 weeks. *INITIAL* (4) Patient will reduce DVAT by 2 lines for improved VOR functioning in 4 weeks. *INITIAL* (5) Patient will reduce convergence distance from 25 cm to 12 cm in 4 weeks. *INITIAL*
Therapist-Selected Goals at First Re-Evaluation	(1) Patient has a good understanding of home exercise program for carryover from PT sessions in 2 weeks. *ACHIEVED* (2) Patient will reduce score on the Dizziness Handicap Inventory by 18 points from 84/100 to 66/100, demonstrating reduced fall risk status in 4 weeks. *ACHIEVED* (3) Patient will improve single limb stance eyes closed up to 10 s to allow patient to ambulate with decreased risk of falling in 4 weeks. *ACHIEVED* (4) Patient will reduce DVAT by 2 lines for improved VOR functioning in 4 weeks. *ONGOING* (5) Patient will reduce convergence distance from 25 cm to 12 cm in 4 weeks. *ACHIEVED* (6) Reduce Fukuda Stepping Test errors by 25 degrees and 10 cm to demonstrate improved postural awareness and trunk and LE proprioception in 4 weeks. *INITIAL* (7) Reduce BESS errors by 5 to demonstrate improved balance in 4 weeks. *INITIAL*
Therapist-Selected Goals at Second Re-Evaluation	(1) Patient will reduce DVAT by 2 lines for improved VOR functioning in 4 weeks. *ONGOING.* (2) Reduce Fukuda Stepping Test errors by 25 degrees and 10 cm to demonstrate improved postural awareness and trunk and LE proprioception in 4 weeks. *ACHIEVED* (3) Reduce BESS errors by 5 to demonstrate improved balance in 4 weeks. *ACHIEVED*

10.16–15.24 cm (Cooper et al. 2010). He was asymptomatic with the head thrust test to the right, demonstrated improved visual acuity on the DVAT, and met the norm for his age on the single leg stance test (Herdman et al. 2007; Springer et al. 2007). The patient reported feeling "a great deal better" on the Global Rating of Change (GROC) scale by the first follow-up (Kamper et al. 2009).

At the first re-evaluation, the patient initiated participation in higher level balance and gait speed testing. He demonstrated 21 errors on the Balance Error Scoring System (BESS) test, 53.51 cm of displacement at 110° on the FUKUDA stepping test (FST) over 100 steps, and a gait speed of 2 m/s on the 10 m walk test (10mWT). CJPSET was set up as prescribed by Revel et al.; the patient correctly returned to center once per five trials of left cervical rotation and extension, and twice per five trials of right rotation (Revel et al. 1991). The patient demonstrated cervical ROM limitations in bilateral lateral flexion and left rotation (Fletcher and Bandy 2008). On manual joint assessment, right side-glide of the patient's lower cervical spine and posterior glide of his atlantooccipital (OA) joint were deemed hypomobile. After the first re-evaluation, the patient was treated once a week for four weeks until the second re-evaluation, as he returned to work full-time and demonstrated marked improvements in dizziness symptoms.

By the second re-evaluation, the patient reported 0/10 dizziness at best and worst and achieved normalcy on the head thrust test. The patient improved from 21 to 6 errors on the BESS test, achieving the norm for both age-matched healthy adults and healthy males (Iverson et al. 2008). The patient demonstrated a decrease in angle of rotation from 110° to 40°, meeting MDC of 23° for his age on the FST (Bonanni and Newton 1998). The patient improved his gait speed from 2 m/s to 3.33 m/s, achieving MCID despite being faster than the average community ambulation to begin with; he also met the gait speed norm for fast ambulation for his age and gender by the second re-evaluation (Bohannon 1997). The patient made gains greater than MDC for cervical ROM in all abnormal cervical motions and achieved normalcy in manual segmental motion testing of his OA joint. The patient scored 5/5 correct on CJPSET with all cervical motions tested (Figure 3), achieving normal cervical proprioception and fewer errors than healthy age-matched controls (Revel et al. 1994; Strimpakos et al. 2006).

When the patient's dizziness was resolved at the second re-evaluation, he was discharged to a home program. The patient was advised to follow-up with a neurosurgeon and to pursue further physical therapy more specific to the Chiari malformation symptoms.

Table 4. Interventions. Therapeutic exercise, neuromuscular re-education, functional activities.

Treatment Session 1	Treatment Session 2	Treatment Session 3	Treatment Session 4
• Initial Evaluation • Bike x 10 min • X1 viewing – vertical and horizontal head turns, 3x in each direction • Cervical laser proprioception x 2 sets • Balance progression: normal stance, Romberg stance, staggered stance w/EO and EC • HEP: X1 viewing at 2 Hz, neighborhood walks as tolerated	• Bike x 10 min • Lateral visual tracking x 1 min (2 Hz) • Lateral head tracking x 2 mins, w/1 min break in between (2 Hz) • Vertical head tracking x 2 mins, w/1 min break in between (2 Hz) • Normal stance x 30 sec on foam, Romberg stance x 30 sec x 2 on foam, staggered stance x 30 sec on floor • SLS on floor 30 sec x 2 on each leg • Gait w/vertical head turns – 12′ x 10 • Gait w/horizontal head turns – 12′ x 10	• Bike at level 3.5 x 10 min • Lateral head tracking 2 × 1 min, with 2 min break in between (2 Hz) • Vertical head tracking 2 × 1 min, with 2 min break in between (2 Hz) • Romberg stance on floor x 30 sec. • Wide tandem-stance w/each leg leading 4 × 30 sec • Tandem stance w/each leg leading 2 × 30 sec • WBOS on ½ foam roller 4 × 30 sec • Suboccipital "yes" 2 × 1 min • Suboccipital "no" 2 × 1 min	• Bike level 3.5 alt backward and forward each min x 10 min • UT stretch 2 × 30 sec • Romberg stance on floor x 30 sec. • Tandem stance w/each leg leading 2 × 30 sec • WBOS on ½ foam roller 2 × 30 sec • Bead convergence task x 1 min • Chin tucks 2 × 1 min • Chin tucks w/beach ball 2 × 1 min • Cervical distraction • Suboccipital release • UT manual stretch
Treatment Session 5	**Treatment Session 6**	**Treatment Session 7**	**Treatment Session 8**
• Bike level 3.5, alternating backward and forward each min x 10 min • Beach ball chin tuck 3 × 10 • Gait w/2 lb. ball tossing fwd 2 x 40′ • Gait w/horizontal head turn, 2 lb. ball tossing 2 x 40′ • Gait w/vertical head turns and ping pong ball tossing 2 x 40′ • SLS on floor 30 sec on each leg • ½ foam roller WBOS 2 × 30 sec, narrow base of support 2 × 30 sec, tandem stance w/each LE leading 2 × 30 sec • VBI testing • Cervical spine bio-mechanical assessment • Suboccipital release • Right cervical spine facet opening glides	• Treadmill (% of incline): 0–2 (0%), 2–4 min (0.5%), 4–6 min (1.0%), 6–8 min (1.5%), 8–10 min (2.0%) at 5.5 mph jog • Beach ball chin tuck 3 × 10 • Prone chin tucks 3 × 10 • Gait w/vertical head turns and ping pong ball tossing 2 x 40′ • Vertical head tracking 2 × 1 min w/2 min break in between (2 Hz on metronome) • Lateral visual tracking x 1 min (2 Hz) • X1 Viewing – vertical and horizontal head turns x 3 each direction. • Cervical laser proprioception x 2 sets. • Single-leg RDL w/orange cone tap x 10 on each side. • Over the shoulder 2 lb. ball toss, right x 25 and left x 25	• Treadmill (% of incline): 0–2 min (0%), 2–4 min (0.5%), 4–6 min (1.0%), 6–8 min (1.5%), 8–10 min (2.0%) at 3.5 mph walk • UT and SCM stretch x 20 sec on each side • Single Leg RDL w/orange cone tap in arc x 4 circuits on each LE • Over the shoulder 2 lb. ball toss alternating right x 10 and left x 20 • Rebounder with SLS and toe touch x 30 on left LE. • Rebounder w/SLS x 30 on each LE • Cervical distraction. • Suboccipital release. • Right cervical spine facet opening glides • Supine and prone chin tucks, UT/levator stretch, convergence with pen, brock string convergence saccades, SLS	• First Re-Evaluation
Treatment Session 9	**Treatment Session 10**	**Treatment Session 11**	**Treatment Session 12**
• Treadmill (% of incline): 0–2 min (1.0%), 2–4 min (2.0%), 4–6 min (3.0%), 6–10 min (3.5%) • Laser tracing 2 × 1 min circles CW and CCW • Laser tracing x 1 min Romberg stance foam CW, CCW • Romberg stance foam rebounder w/3 lb. ball: forward throws 2 × 1 min, throws to left 2 × 1 min • Bosu bridges x1min • ½ foam roller tandem stance, right LE leading 2 × 30 sec; WBOS 2 × 30 sec • Suboccipital "yes" and "no" 2 × 1 min • Cervical distraction • Suboccipital release • Right cervical spine facet opening glides • Bilateral UT/SCM STM	• Treadmill (% of incline): 0–2 min (1.0%), 2–4 min (2.0%), 4–6 min (3.0%), 6–8 min (3.5%), 8–10 min (4.0%). • Laser tracing w/10 sec chin tuck: 2 × 1 min circles CW, CCW; x 1 min Romberg stance on foam CW, CCW; SLS on foam x 2 min CW, CCW • Romberg stance, EC 2 × 30 sec • Romberg stance, EC w/manual perturbation 2 × 30 sec • Romberg stance, EC transition into SLS on each leg 2 × 30 sec • Cervical distraction • Suboccipital release • Right cervical spine facet opening glides • Bilateral UT and SCM STM	• Treadmill x 10 min at 4.0% incline • Laser tracing w/10 sec chin tuck holds: 2 × 1 min circles CW, CCW; x 1 min Romberg stance on foam CW, CCW; SLS on foam x 2 min CW and CCW • Bosu ball squats 3 × 10. • SL RDL w/orange cone tap on foam in arc x 4 circuits on each LE • Cervical distraction • Suboccipital release • Right cervical facet opening glides • Bilateral UT STM • AA joint flexion rotation mobilization gr 4 each side • OA retraction in neutral and bilateral 30° side-bend	• Second Re-Evaluation

Abbreviations: Tx = Treatment Session. EO, EC = Eyes Open, Eyes Closed. HEP = Home Exercise Program. L/R = left/right. WBOS = wide base of support. Pt. = patient. w/ = with. min = minute. sec = seconds. ROM = range of motion. SLS = single leg stance. LD = Lyme Disease. EC/EO = eyes closed/open. UT = upper trapezius. VBI = vertebrobasilar insufficiency. WFL = within functional limits.

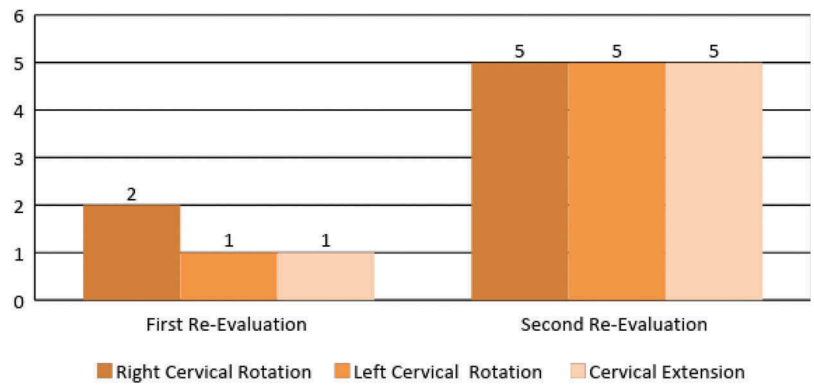

Figure 3. Cervical joint position sense test.

Discussion

This case report presents an effective treatment program for a patient with multiple symptoms secondary to UVH. The patient made significant strides on several symptoms between three evaluations. While the course of recovery from UVH may be varied and depended on the cause, one study suggested that an average patient may take six to eight months to recover without any treatment (Alpini et al. 2014). However, vestibular rehabilitation has been suggested helpful in minimizing the temporal course of recovery and typically consists of systematic compensation to appropriate stimuli with adaptation, substitution, habituation, and balance training exercises (Arnold et al. 2017; McDonnell and Hillier 2015). According to the literature, vestibular hypofunction rehabilitation is united on several fronts. Four principal goals for this population include improved gaze stability, improved postural stability, decreased vertigo, and enriched activities of daily living (Han et al. 2011). Principal interventions include pathology education, habituation, gaze stabilization, balance training, and walking (Hall et al. 2016a, 2016b; Herdman and Clendaniel 2014). The most common specific vestibular rehabilitation exercises prescribed by therapists include head–eye coordination, VOR × 1 (patient views stationary object with horizontal and/or vertical head turns), static standing, and VOR cancellation (Whitney and Sparto 2011). Such intervention can significantly benefit DHI scores and balance testing in patients with uncompensated UVH (Hall et al. 2016a, 2016b). As the patient was diagnosed with UVH at the physical therapy evaluation and demonstrated deficits on the DHI, each of these interventions were incorporated into the patient's plan of care. Between initial evaluation and first re-evaluation, the patient's symptoms of dizziness, headache, and cervicalgia were improved on NPRS, DHI, and VOR testing. The patient demonstrated improved visual acuity on the DVAT, though a difference of four lines between the static and dynamic visual acuity measures indicated underlying vestibular dysfunction. In addition, the patient continued to demonstrate deficits in postural stability and balance. Therefore, between the first and second re-evaluation, the patient's home exercise program and supervised rehabilitation focused on these latter deficits.

The primary deficits noted on DHI at the second re-evaluation included emotional deficiencies (i.e. ongoing depression and frustration regarding return to work prior to feeling ready) and deficiencies in complete return to vocational and recreational activities secondary to the patient's headache and resultant difficulty concentrating. The DVAT, a test requiring intense concentration and normal bilateral cervical rotation, did not improve by the second re-evaluation likely due to the aforementioned limiting factors. In addition, the improvement in GROC scores was seen by the second re-evaluation, indicating an improved quality of life. However, this result did not synchronize with NPRS presenting 8/10 in worst. The reason might be due to the patient being asked to return to work full time after the first re-evaluation. Per patient's subjective report, driving 1.5 h to and from the place of work in rush-hour traffic, loud noises, and frequent head turning at work might be the causes for his headache rating to spike.

Chiari malformations are generally treated with medications and/or surgery. However, surgical outcomes for Chiari malformations are poor at best. Dones et al. (2003) reported that in 27 surgical cases of this rare cerebellar malformation, only one patient's cervicalgia improved, one patient's headache resolved, and three patients' vertigo resolved. Previous literature has suggested that gaze stabilization, vestibular habituation, balance training, and gait training may be helpful to treat patients' central vertigo (Hall et al. 2016a, 2016b; Han et al. 2011; Herdman and Clendaniel 2014). Patients with central vertigo, headache, and neck pain may make significant improvements by participating in multi-modal therapies including manual therapy and therapeutic exercise (Bracher et al. 2000). In addition, physical therapy for postural performance in patients with vertigo significantly improved both cervicalgia and dizziness symptoms (Karlberg et al. 1996). The connections between these interwoven balance systems are further strengthened by evidence suggesting that balance training improves both cervicalgia and cervical JPSE (Beinert and Taube 2013). At the second re-evaluation, the patient shared that he followed up with a neurologist the week prior and was newly diagnosed with Chiari malformation. Since Chiari malformations are typically congenital, the interventions in this case report seemed to be effective in retrospect on patient's symptoms due to not only UVH, but also Chiari malformation. Therefore, the physical therapy approach presented here may also be applicable for patients with central cause of dizziness secondary to Chiari malformation.

One of the limitations in this case report is that lacking exact cervical ROM measurements, BESS, Fukuda, Ten Meter Walk Test, CJPSET, and cervical joint accessory motion testing from the initial evaluation due to the amount of time spent obtaining a thorough past medical history from the patient. This makes it difficult to track improvements or detriments of cervical range, static and dynamic balance, gait speed, cervical proprioception, and joint play made between the initial evaluation and the first re-evaluation. Another limitation is the complex medical history (i.e. Lyme disease, motor vehicle accident, and ear infection) besides the medical diagnoses of UVH and Chiari malformation made it difficult to determine the causes of the patient's clinical symptoms. In this report, the physical therapist focused on treating patient's symptoms. However, the functional goals such as return to work could be addressed more in the treatment program.

While clinical studies utilizing CJPSET and laser proprioceptive training in conjunction with traditional vestibular rehabilitation therapy are sparse, this report adds case experience to the body of literature available to clinicians regarding laser testing and training, an objective measure for vestibular exam and management. In addition, this report suggests the need for future research involving CJPSET. Directions for future applications include comparing knowledge of results versus knowledge of performance on CJPSET to encourage effective and efficient skill acquisition, gauging CJPSET after cardiovascular training to study the effects of fatigue on cervical proprioception, gauging CJPSET after patient participation in motor imagery to assess the effects of intrinsic feedback on cervical proprioception, gauging CJPSET after muscle vibration to assess short- and long-term effects of muscle spindle afferent activation on cervical proprioception, or gauging CJPSET after virtual reality interventions to assess the effects of active cervical kinematic control on cervical proprioception. Exploring methods to maximize CJPSET performance may guide clinicians in formulating efficient and effective means to train JPSE in the future.

Conclusions

In conclusion, this case report demonstrates an effective physical therapy plan of care for a patient with peripheral vestibular hypofunction. By focusing on cervical proprioceptive training as well as the traditional visual, vestibular, and somatosensory treatments, the patient's symptoms were improved on self-reported dizziness outcomes, full vertigo examination, static and dynamic balance, gait speed, and cervical JPSE.

Declaration of Interest

The author reports no conflicts of interest.

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