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Can a structural leg length discrepancy contribute to persistent concussion symptoms? A case report

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In the past several years, concussions and post-concussion syndrome (PCS) have become more commonly recognized conditions. However, with limited physiological explanation for post-concussion syndrome, there is also limited evidence supporting effective treatment. The vestibular system plays a role in postural reflexes and coordinated eye and cervical spine movements and is often disrupted in patients with prolonged concussion symptoms. This disruption has contributed to some of the most debilitating symptoms in PCS patients including dizziness, nausea, and balance deficits. Ongoing, post-concussion, vestibulo-ocular/cervical-ocular disruption due to an underlying

Une différence structurelle de longueur de jambe peut-elle contribuer à la persistance des symptômes de commotion cérébrale? Un rapport de cas

Au cours des dernières années, les commotions cérébrales et le syndrome post-commotion cérébrale (SPC) sont devenus des problèmes de santé plus couramment reconnus. Cependant, l'explication physiologique du syndrome post-commotion cérébrale étant limitée, les preuves d'un traitement efficace sont également limitées. Le système vestibulaire, qui joue un rôle dans les réflexes posturaux et les mouvements coordonnés des yeux et de la colonne cervicale, est souvent perturbé chez les patients présentant des symptômes de commotion prolongés. Cette perturbation a contribué à certains des symptômes les plus débilitants chez les patients atteints de SPC, notamment des vertiges, des nausées et des déficits d'équilibre. Une perturbation vestibulo-oculaire/cervico-oculaire continue, post-commotion cérébrale, due à une

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structural leg length discrepancy as a contributing factor has not been previously described in the literature. A case of PCS with initial conservative treatment of their structural leg length discrepancy and subsequent vestibulo-ocular/cervical-ocular rehabilitation is presented.

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KEY WORDS: leg length discrepancy, leg length inequality, concussion, vestibular system, post-concussion syndrome, proprioception, vestibular-ocular reflex, cervico-ocular reflex

différence structurelle sous-jacente de longueur de jambe comme facteur contributif n'a pas été décrite précédemment dans les documents scientifiques. Nous présentons un cas de SPC avec un traitement conservateur initial de la différence structurelle de longueur de jambe et une réadaptation vestibulo-oculaire/cervico-oculaire ultérieure.

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MOTS CLÉS : différence de longueur de jambes, inégalité de longueur des jambes, commotion cérébrale, système vestibulaire, syndrome post-commotion cérébrale, proprioception, réflexe vestibulo-oculaire, réflexe cervico-oculaire.

Introduction

The vestibular system provides the body with the sense of balance and the information about the body's position that allows rapid compensatory movements in response to both self-induced and externally generated forces.[1] We are normally unaware of its function, however, the vestibular system plays a key role in both postural reflexes and coordinated eye and cervical movements.[1] The human body integrates the vestibular, oculomotor and somatosensory system to allow humans to optimally navigate and function within complex visuospatial environments while maintaining postural control and visual equilibrium.[2,3] Highly specialized networks interact on multiple levels of the craniospinal axis to regulate gait, maintain balance, allow postural control, and coordinate eye and cervical spine movements.[2]

The ability of an individual to perceive the direction of gravity is essential for balance and orienting themselves in their environment.[4] Clemens *et al*.[5] proposed a model of gravity perception that included information from both the head and the body. Fraser *et al*.[4] did a series of experiments to determine the extent of the contribution of these inputs by measuring subjective visual vertical (SVV) for the input from the head, and subjective haptic vertical (SHV) for the input from the body.

Haptic refers to the perception of objects through the sense of touch and proprioception. SHV is the individual's sense of vertical through haptic stimulus only. Anastasopoulos *et al*.[6] suggested that SVV was strongly influenced by vestibular and ocular input while SHV is overwhelmingly influenced by somatosensory input and may be independent of vestibular imbalance.

Although positional compensation due to SVV and SHV may vary, Fraser *et al*.'s[4] multi- study article adds a further layer by suggesting that these two estimates may inform each other through an "indirect pathway". This "indirect pathway" is the perceived position sense of the cervical spine relative to the other two systems. They suggest that the neck converts one estimate of vertical into the reference frame of the other in order to inform the overall position to the brain[4]. The paper by Fraser *et al*.[4] was published directly on the heels of the paper by Marshall *et al*.[7] further adding to their position that concussion symptoms likely have a cervicogenic component[7].

When the vestibular system becomes injured/damaged, normal body functions such as balance, sense of orientation in space and eye movements while the head is moving are all negatively affected.[1] As research on the vestibular system continues to emerge, there have been several pathological conditions that have been linked to disruptions in vestibular function. A common condition among athletes is concussion and post-concussion syndrome (PCS). Concussions are heterogeneous injuries resulting in physical, cognitive, emotional and sleep related symptoms.[8] It is estimated that there are 1.6 to 3.8 million sport-related concussions (SRC) annually in the

United States.[2] The physical symptoms include vestibular-oculomotor impairment through the vestibulo-ocular reflex (VOR) and it may delay recovery if left untreated.[8] Symptoms arising from the vestibulo-ocular system have become amongst the most debilitating and disabling when associated with concussion[2] and have been identified as a prognostic factor for worse symptom burden, decreased cognitive performance, and longer recovery[3].

Up to 81% of athletes exhibit vestibular-associated signs following concussion.[3] Most concussion cases resolve in seven to 10 days, however 10 to 15% of cases can develop persistent symptomatology that lasts weeks, months or even years.[7] While PCS has been defined by the International Classification of Disease (ICD) as the persistence of three or more symptoms for four weeks or more, there is yet to be a clear physiological explanation for its development.[7]

While vestibular rehabilitation has shown to be an effective intervention for treatment of post concussive disorders, there are still a significant number of patients who have undergone this treatment with little to no success.[9] This raises the question of why, and what could be interfering with the improvement in vestibular symptoms in these cases.

Leg length discrepancies (LLD) are quite common accounting for three to 15% of the population and are present with both structural and functional scoliosis.[10] In many of the cases, the cause is unknown, and the difference is within 2cm. Any inequalities smaller than 2cm are thought to rarely cause a problem.[10] Symptomatic leg length discrepancies have most commonly been treated with internal or external shoe lifts. Custom foot orthoses and heel lifts were found to reduce spinal curves in juvenile patients with mild idiopathic scoliosis and have shown to be an indicated treatment regimen in the presence of certain types of functional scoliosis.[11]

To our knowledge, there are no case reports or other studies in the literature describing a possible link between persistent vestibulo-ocular-cervical concussion symptoms and a congenital/structural leg length discrepancy or inequality. The purpose of this case report is to describe the treatment of persistent post-concussion symptoms in a patient found to have a congenital leg length inequality utilizing heel lift therapy and subsequent vestibular rehabilitation following leg length optimization.

Case presentation

A 59-year-old female, former dragon boat athlete presented to the chiropractic clinic with a chief complaint of low back pain that she had had for greater than 30 years. Recently, she had begun to experience calf pain and spasm with walking and standing. She also reported a complicated concussion history that she felt had left her with ongoing balance and dizziness issues amongst other potential concussion related symptoms since her first concussion. She had seen a neurologist who recommended a balance specialist physiotherapist which helped somewhat at the time. Details of the program were sparse due to the length of time since her participation (14 years prior to presentation). She reported several other co-morbidities including depression, bipolar disorder, previous bulimia, high blood pressure (medicated) and pre-diabetes. Other past medical history included bilateral knee replacement surgery with another surgery done on the left knee to repair a fracture of the prosthesis cement; chronic difficulty breathing (MD determined that it was not due to asthma); previous pulmonary emboli due to DVT following her knee surgeries (which she had examined due to current calf pain and was cleared); and three previous MVA's starting in 1999 with an increase in neck pain each time. She also reported the previous use of orthotics that did include a heel lift correction but was no longer wearing them.

Her concussion history included an initial concussion following a dragon boating accident in which she had fallen out of the boat and was struck on the head by another dragon boat. This incident occurred 14 years prior to presentation at the chiropractic clinic. A second concussion 10 years prior to presentation was reported and occurred when she was climbing a scaffolding and hit her head as she ascended. This was not a work related incident. A third concussion seven years prior to presentation was reported and occurred when she was acting as a volunteer, felt ill during an event and fell and hit her head. She reported that she was no longer allowed to be a volunteer following this accident due to safety concerns surrounding her dizziness and balance issues. The patient was asked to fill out a SCAT 5 symptom scale and had 20/22 symptoms and a severity score of 72/132 (See Figure 1).

The patient reported her height as 166 cm (5'5 ½") and weight as 128 kg (282 lbs) (BMI – 46). A seated neuro-

Step 2: Symptom Evaluation

	T = 0	T = 0 + 2 mos.	T = 0 + 3.5 mos.
Please check: ☐ Baseline ☑ Post-Injury	Post-Injury	Post-Injury	Post-Injury
	7 yrs since last concussion/15 years since first concussion	(7 yrs since last concussion/15 years since first concussion)	(7 yrs since last concussion/15 years since first concussion)
Headache	0	0	0
"Pressure in head"	0	0	0
Neck Pain	1	1	0
Nausea or vomiting	1	0	0
Dizziness	4	0	0
Blurred Vision	2	1	1
Balance Problems	6	1	1
Sensitivity to light	1	0	0
Sensitivity to noise	4	1	0
Feeling slowed down	4	1	0
Feeling like "in a fog"	4	0	0
"Don't feel right"	4	1	0
Difficulty concentrating	5	1	0
Difficulty remembering	4	1	0
Fatigue or low energy	6	1	0
Confusion	2	0	0
Drowsiness	5	1	0
More emotional	3	1	0
Irritability	2	1	0
Sadness	4	1	0
Nervous or Anxious	4	0	0
Trouble falling asleep (if applicable)	6	1	0
Total number of symptoms	20 of 22	14 of 22	2 of 22
Symptom severity score	72 of 132	14 of 132	2 of 132
Do your symptoms get worse with physical activity?	Y N	N	Y N
Do your symptoms get worse with mental activity?	Y N	Y	Y N
If 100% is feeling perfectly normal, what percentage of normal do you feel?		80%	
If not 100%, why?		depression	

Scale: none 0; mild 1–2; moderate 3–4; severe 5–6.

Figure 1.
SCAT 5 Concussion Symptoms Severity and Total Symptom Score of the Patient
a) Time = 0 (1st assessment) b) Time = 0 + 2 months c) Time = 0 + 3.5 months

logical exam found the following: her upper and lower limb neurologic exams including motor, sensory and reflexes were within normal limits (WNL); pathologic reflexes including Hoffman's (negative bilaterally) and plantar response (down going bilaterally) were WNL; and cerebellar testing including upper and lower limb rapid alternating movement, point to point, graphesthesia and stereognosis (bilaterally) were WNL. Her cranial nerve exam was WNL except for the following: on H-pattern testing, the patient reported increased dizziness (she felt she was spinning, not the room) with transition (smooth pursuit) and repeat transition (saccades) with both horizontal and vertical (from midline to upper quadrant bilaterally) with no nystagmus noted; increased dizziness (similar to above) and double vision with convergence reaching approximately 10 to 12 cm to her nose before her eyes would diverge; and fixed gaze testing increased her dizziness (similar to above) with both cervical spine rotation and cervical spine flexion which she reported was the worst of the movements. Modified Balance Error Scoring System (m-BESS) revealed two errors with double leg stance (feet together), six errors with tandem stance and eight errors with single leg stance (16 errors total). No other neurologic testing was undertaken due to her increase in symptoms. On standing and prone examination, a moderate right thoracolumbar scoliosis was noted (32° on x-ray) with significant hypertonicity of the erector/multifidus musculature (part of her low back complaint). Iliac crest height palpation in standing revealed a notably lower left iliac crest. A prone leg length check revealed a left short leg (approximately 3/4" – 1 inch (2 cm – 2.54 cm), prone palpation of the posterior inferior iliac spine suggested they were even side to side, and prone left hip extension revealed a decreased anterior translation of the left sacral base. These findings suggested a structural leg length inequality with a short-left leg and a corresponding left sacral base dysfunction.

Following the history and physical exams, the patient was diagnosed with a suspected structural short left leg, chronic PCS, and suspected lumbar spinal stenosis. Her plan of management included:

1. Progressive heel lift therapy to determine optimal correction;
2. A seated wedge if needed;
3. Once her optimal heel lift height was determined (evaluated by improving signs and symptoms and SCAT 5 scores), begin soft tissue therapy on the remaining affected tissue; begin visual/vestibulo-ocular/cervical-ocular retraining based on her "new normal"; and
4. Swimming/aquatic therapy to help with weight loss/improve fitness goal.

The patient attended six visits over a period of six weeks. Minimal soft tissue therapy was applied to her lower back and cervical paraspinal musculature. The patient was asked to use a seated wedge while sitting with the side and size of the wedge determined by her response to a self H-pattern assessment while seated (i.e., try both sides and go with the side with lesser dizziness following the test). The heel lift was progressed as tolerated from an A lift (1/8") to a D lift (1/2") with her symptoms being monitored, a SCAT 5 symptom scale completed, and her convergence, H-pattern and fixed gaze being retested (with the heel lift in her shoe). On the seventh visit, after a week with the D lift, she reported an increase in low back and calf pain and the decision was made to return to the C lift. Her lower back and calf spasms returned to prior, better levels and it was felt the C lift was the correct size.

Following her return to a C heel lift, her convergence had improved to 0.5 cm at which point her eyes diverged and she had only minimal dizziness, her H-pattern testing caused no dizziness or unsteadiness, and her fixed gaze testing caused only minimal dizziness with rotation or flexion. Unfortunately, due to time constraints on this visit, modified BESS testing was not able to be completed. Also of note, the hypertonicity of her cervical, thoracic, and lumbar spine musculature had decreased considerably both subjectively and objectively.

The patient attended six more visits over a six-week period (treatment was discontinued due to the shutdown associated with the COVID pandemic). During this phase of treatment, more aggressive soft tissue therapy to her cervical, thoracic, and lumbar spine, manual therapy (including spinal manipulative therapy to the thoracolumbar spine) and vestibulo-ocular-cervical exercises utilizing a laser pointer mounted on a bike helmet were initiated.

An early exercise prescribed was one designed to re-establish neck proprioception during cervical spine rotation. The patient, while wearing their C heel lift, stood with their feet in a comfortable position, the laser pointed at a target on the wall (approximate distance to the wall of 152 cm (60") to 214 cm (84")). The patient closed their eyes, rotated their head side to side four to five times in each direction, then attempted to stop in their neutral start position. Any deviation of the laser pointer from the target was noted and the head was corrected to the target before the next repetition. The patient was asked to progress the exercise once the repositioning was successful on a regular basis through the BESS protocol foot positions using the short leg, with lift, as the non-dominant leg.[12]

Another main exercise was to maintain the laser pointer on a central target, determine the left/right/up/down limits of her gaze without symptoms (66 cm (26")) and place targets for these positions (See Figure 2). While maintaining the laser centrally, she was to transition her gaze

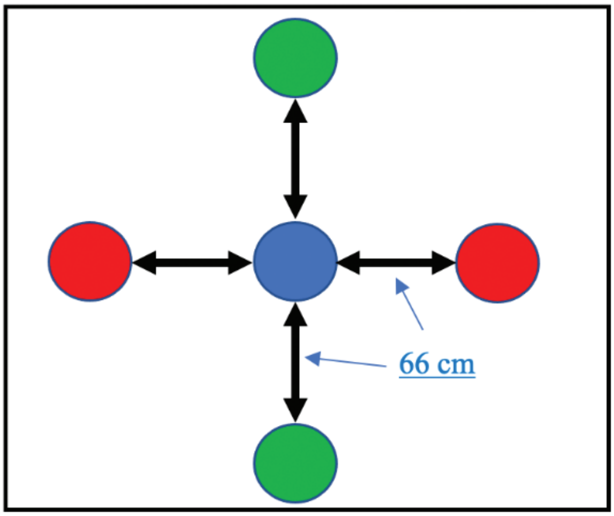

Figure 2.
Schematic of targets

to each of the targets while returning to centre after each movement to a metronome (40 bpm). This was done both seated and standing 92 cm (36") from the wall. She was asked to try for one minute but was nauseous and dizzy after 40 seconds. Due to her increased symptoms, her time was reduced to 30 seconds (seated and standing) 1X every other day. Over the next five weeks, she was able to progress to one minute seated and standing once per day, five days per week with little to no increase in symptoms. Following her last visit, she was asked to complete another SCAT 5 symptom scale which had improved to 2/22 symptoms and 2/132 severity. Again, unfortunately due to the shutdown, her m-BESS was not retested. Over this period, her SCAT 5 symptom scales were as follows (see Table 1):

Table 1.
Patient's total symptoms and symptom severity

Time	Number of symptoms (X/22) (SCAT 5 Symptom Scale)	Symptom Severity (X/132) (SCAT 5 Symptom Scale)
At initial	20/22	72/132
Initial + 2 months	14/22	14/132
Initial + 3.5 months	2/22	2/132

The patient was unable to begin pool therapy to address goal #4 of her treatment plan, again, due to the shutdown. Due to her continued, but improved, walking issues, radiographs of her lower back and pelvis were ordered approximately six weeks following presentation and revealed the aforementioned scoliosis, severe DDD from L3 to L5, moderate DDD L1/2 and L5/S1, a Grade 1 isthmic spondylolisthesis at L5/SI, moderate facet arthrosis from L2 to S1, mild DJD of bilateral SI and hips and moderate osteopenia. The radiographs were taken recumbently.

Discussion

The vestibulo-ocular reflex (VOR) regulates gaze stabilization during head acceleration, the vestibulo-spinal reflex (VSR) coordinates head, neck, and trunk positioning during dynamic body movements, and the cervico-ocular reflex (COR) is an ocular stabilization reflex initiated with cervical spine rotation.[2] When dysfunctions develop within these systems, it can have adverse effects on related subsystems generating complex symptoms and impairments with difficulty localizing them to one neural subsystem. Symptoms stemming from the vestibulo-ocular system include dizziness, gait instability, fogginess, blurred vision, and difficulty focusing.[2] Common visual symptoms include blurred vision, diplopia, difficulty reading or motion sensitivity which have been found to arise from deficits with accommodation, convergence, pursuits, saccades, and fixations.[2] Symptoms arising from the vestibulo-ocular system have become amongst the most debilitating and disabling when associated with concussion.[2] On the first SCAT 5 (see Figure 1 a), the patient reported symptoms consistent with vestibulo-ocular findings including: dizziness, balance problems, feeling like "in a fog", blurred vision, difficulty concentrating and remembering and nausea or vomiting. Objectively, the patient had deficits in smooth pursuits, near point convergence, fixations and saccades that resulted in dizziness and balance issues.

Concussions are heterogeneous injuries which, to this day, are still considered one of the least understood injuries.[7,8] There is no clear physiological explanation for PCS and evidence surrounding possible causes of PCS is limited. However, it has been proposed that PCS can be divided into subtypes; physiologic PCS, vestibulo-ocular PCS, and cervicogenic PCS[2], with theories surrounding their mechanism that include metabolic dysfunction, continued axonal dysfunction, psychological factors, altered cerebral blood flow and dysfunction of the cervicogenic pain and proprioceptive mechanisms[7]. Due to the vast developing nature of concussions and PCS and the little evidence surrounding causes, post-concussion examinations should at minimum include full neurological, and cerebellar function, with a thorough assessment of balance, gait, cognitive function, and the patient's vestibular system.[2] Vestibular oculomotor screening (VOMS) has begun to be used as a part of the concussion assessment.[8] The VOMS assessment tool evaluates vestibular and oculomotor systems after concussion and assesses seven components; smooth pursuit, horizontal and vertical saccades, horizontal and vertical VOR, visual motion sensitivity and near point convergence (NPC).[8] With proper rehabilitation of the vestibular system, the scores of the VOMs should improve from the baseline test post-concussion. Although not all of the VOMS assessment was completed with our patient, her smooth pursuit, saccades, fixations and near point convergence all improved from baseline after heel lift therapy followed by vestibulo-ocular-cervical rehabilitation.

Vestibular rehabilitation programming is designed to improve function of the VOR and COR by including depth perception training, somatosensory retraining, dynamic gait training and aerobic conditioning. The exercises have shown to improve fixation, pursuit, predictable and unpredictable saccades, vergence, and accommodation.[2] A study focusing on weekly cervical spine and vestibular rehab treatments in subacute and chronic concussion patients resulted in 73% of athletes becoming asymptomatic and cleared for return to sport compared to 7% in the control group.[9] The benefits of vestibular rehabilitation for the post-concussion population have been reproduced in other studies, and moderate level evidence to support this theory in a 2017 systematic review of the literature.[13] In our case, the patient had previously participated in vestibular rehabilitation (although her recollection of the details of the program were sparse) with limited success. Following heel lift therapy to optimize her structural leg length discrepancy, she again participated in vestibular rehabilitation further improving her SCAT 5 symptom scale from 14/22 symptoms and 14/132 symptom score to 2/22 and 2/132 respectively (See Figure 1b and c).

Disruption or injury to the vestibular system has been linked to other biomechanical issues including, but not limited to, adolescent idiopathic scoliosis (AIS).[14,15] Despite the high prevalence of the condition, the etiology behind AIS remains unclear. Since the vestibular system influences the vestibulospinal pathways, the hypothalamus, and the cerebellum, it is plausible to believe that this could account for the morphological and neurosensory changes observed in AIS.[14] It could also be that AIS patients use strategies to compensate for possible head position changes and spinal asymmetry caused by morphological deformations of the spine through vestibular and somatosensory systems.[16] In both theories, it is made clear that there are changes to the vestibular system in this population. Our patient had a 32° scoliosis, likely since she had reached skeletal maturity based on her long history of back pain. It is likely she would have had an AIS diagnosis until the functional nature of her scoliosis due to the LLD was discovered.

Subjective visual vertical (SVV) is a sensitive sign of verticality perception.[15,17,18,19] It relies on both visual and vestibular input and is reported to be the most sensitive sign of vestibular tone imbalance in the roll plane.[6,15,19] Vestibular tone imbalance can be the result of lesions in the central and/or peripheral vestibular pathways. In a study by Cakrt *et al*.[15], they found that patients with adolescent idiopathic scoliosis (AIS) had a significantly larger deviation in SVV versus age-matched controls. Their findings suggest that scoliosis in AIS may be the result of a vestibular impairment due to an imbalance in these vestibular pathways. Correspondingly, it also suggests those with scoliosis have a slightly askew sense of verticality from a visual standpoint despite the ability of the body to adapt to the vestibular deficits. In their study[15], more than 20% of patients with AIS had an average deviation in their SVV of more than 2°. Unfortunately, there was no measurement of leg lengths mentioned in the study by Cakrt *et al*.[15]

Scoliosis patients are also well known to present with leg length discrepancies.[10] Back pain, lower extremity pain and degenerative conditions have been shown to correlate with inequalities in leg length.[20] A common theory is that if you can restore leg-length inequalities through the use of custom-made stabilizing orthotics and/or lifts then you can improve the proprioceptive sensory feedback and ability to coordinate body movements, postural alignment and balance.[11] Custom foot orthoses and heel lifts were found to reduce spinal curves in juvenile patients with mild idiopathic scoliosis and have shown to be an indicated treatment regimen in the presence of certain types of functional scoliosis with few adverse effects.[11] In our case, the addition of a heel lift through a progressive approach saw marked changes in muscle hypertonicity and pain in the lower back and neck both subjectively and objectively. Once the pain began to return with the D size lift, the decision was made to return to the C lift and the pain once again subsided to previous levels.

The approach to applying heel lift therapy and the endpoint for height of the correction have limited consensus in the research. A systematic review by Campbell *et al*.[21] acknowledges these limitations and suggested that for traumatic based LLD's (eg. post surgery or fracture) an immediate full correction is warranted, while a chronic, long standing LLD may only require partial correction due to the patient's adaptation to their LLD. Our approach, in this case, was a progressive one to allow the patient to adapt to the change while monitoring for improvement or increase in symptoms. Our case demonstrated the recommendation by Campbell *et al*.[21] by only requiring a partial correction for patients with a chronic LLD (a C heel lift is 3/8" compared to the patient's ¾ - 1" structural difference).

It has yet to be investigated how other tools can be implemented in concussion treatment to target biomechanical changes such as foot orthosis and heel lifts, which have also shown to increase proprioceptive ability.[22,23] If the use of custom-made stabilizing orthotics and/or heel lifts can improve the proprioceptive sensory feedback and ability to coordinate body movements, postural alignment, and balance in scoliosis patients, then the same effect could be possible with patients suffering from PCS if an LLD is identified as in our case.

Limitations

The authors acknowledge the limitations of this case report including subjectively reported measures, and a lack of evidence supporting management using heel lifts. There is also a lack of validity and reliability in the evaluation of LLD generally, including the method used in this assessment. There was also a lack of confirmation of an LLD through a full, bilateral lower body radiograph which would be considered the gold standard, although the routine use of radiographs to check for LLD is not recommended due to unnecessary radiation exposure.

There is also an inherent limitation in all case reports that their results cannot be generalized – they are instead meant to report rare findings and potentially stimulate further research in this area which is the hope of this report.

Summary

This case highlights a unique clinical consideration in a patient with prolonged, post-concussion, vestibulo-ocular-cervical symptoms following several concussive events. Assessing and providing successful conservative treatment for an LLD, followed by vestibular/ocular/cervical rehabilitation in a patient with prolonged post-concussion symptoms has not been previously reported in the literature to our knowledge.

Although speculation on hypothesis in case reports is not usually included, the lack of other reports or studies in the literature linking structural LLD and persistent concussions symptoms may warrant its inclusion in the current report. The lack of similar case reports in the literature begs the following questions: 1) Are these cases so rare that this particular patient is unique and interesting but adds no further value for stimulating future investigation? and/or 2) Has this theoretical link not previously been reported because assessing for LLD in acute or persistent concussion is not a routine part of patient assessment?

The authors of this report suggest it is likely the latter. There is no mention of assessing for LLD in any studies on concussion to our knowledge. In the majority of individuals with LLD, they have been able to compensate for this discrepancy in such a manner that they aren't even aware that they have an LLD let alone seek out treatment for it. We suspect that the vestibulo-ocular-cervical system easily adapts to their LLD under normal circumstances but the adaptation(s) may narrow their ability to then adapt to an injury causing concussion ultimately contributing to ongoing or more severe symptoms and even affecting their capacity to recover.

The authors suspect that if the concussive injury is severe enough, or if there have been repeated concussive injuries (as in our case) that pushes the patient outside of their vestibular-ocular-cervical adaptation to the LLD, the patient's ability to recover becomes more difficult, takes longer, and some aspects may not achieve full recovery leading to prolonged, persistent symptoms. Interestingly, the suggestion that the neck's proprioceptive feedback is able to integrate the SVV and SHV[4] may also prolong recovery if that system has chronic injury related issues. It would also make sense, although there is no supporting literature on this, that the larger the LLD, the greater the adaptation needed to stabilize their vestibulo-ocular-cervical system resulting in a narrower window of potential adaptation to a concussive injury. Thus, the length of time to recovery may in fact be proportional to the size of the underlying structural LLD (with all other aspects of recovery being equal).

In our case, the patient reported chronic lower back pain (likely reducing her SHV), mild, chronic neck pain (likely reducing the integration) and she would likely have an offset of 2° or more SVV due to her 32° scoliosis. The addition of the heel lift reduced both her lower back and neck pain (with the addition of vestibular rehabilitation) and likely improved her SVV. It is possible that the improvement of these three systems followed by vestibular rehabilitation led to her recovery.

Further research studies could explore the relationship of structural LLD and persistent vestibulo-ocular-cervical concussion symptoms. If such a relationship exists, as this case report would suggest, the addition of a simple, inexpensive heel lift may be an effective first step in the treatment of this potential sub-category of post-concussion patients with persistent vestibulo-ocular-cervical symptoms. Once the LLD is optimized, a vestibular/ocular/cervical rehabilitation program may then be more effective in reducing any remaining vestibulo-ocular-cervical symptoms.

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