Stabilizing Vestibular Ocular Reflex in Post Concussion Syndrome

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Abstract

Post concussion syndrome (PCS) is a group of symptoms that occur following a concussion for as long as weeks to months after the incident. PCS symptoms manifest cognitively, psychologically, vestibularly and visually[3]. Feelings of dizziness, vertigo, relentless nausea and imbalance are among the most common symptoms a patient experiences following a concussion or acquired brain injury[1-2]. These symptoms have long been classified as vestibular dysfunction, but the visual component should be considered in rehabilitation. Primarily, because patients with PCS often also suffer from oculomotor dysfunction, which directly effects the vestibular ocular reflexes and exacerbates seemingly vestibular symptoms[1-2]. Neuro-optometric vision therapy leads to improvement in balance between central and peripheral processing systems, as well as an improvement in VOR gain with improved accommodative ability and visual skills[2]. PCS is a multi-system condition that should be treated accordingly, calling on an integrative approach between vestibular physical therapists, occupational therapists, and optometric vision therapy to dull symptoms of dizziness, disequilibrium, and vertigo[1-3,6].

Keywords: dizziness, vertigo, vestibular, vestibular ocular reflex (VOR), post concussion syndrome (PCS), vision therapy

In recent years concussion has become a hot topic in current medical research and literature. It's synonyms include acquired brain injury and mild traumatic brain injury which makes one thing true, concussions result in a traumatized brain caused by physical impact. As a result of brain trauma, it should be apparent that multiple sensory systems can be effected that need to be addressed in recovery. Post concussion syndrome is a group of symptoms that manifest cognitively, psychologically, vestibularly and visually[3]. Feelings of dizziness, vertigo, relentless nausea and imbalance are among the most common symptoms a patient experiences following a concussion or acquired brain injury[1-2]. These symptoms have long been classified as vestibular dysfunction, but the visual component should not be neglected in rehabilitation. Primarily, because patients with PCS often also suffer from oculomotor dysfunction, which directly effects the vestibular ocular reflexes and exacerbates seemingly vestibular symptoms[1-2].

Having an accurate description of the patient experience is an important element of the case history in this patient population. A concise comparison of dizziness, disequilibrium and vertigo is imperative for diagnosis and treatment recommendations. Dizziness is the subjective feeling of floating, light-headedness, or disorientation[2]. The cause may be a disruption of visual, vestibular or somatosensory inputs, or any combination between the three. Disequilibrium is the loss of balance without any illusion of movement and is caused by a disruption in sensory-motor integration[2,6]. Vertigo is the illusion of movement of either one's self or one's surrounding in the absence of movement, and is caused by a disruption between visual, vestibular and somatosensory inputs[2,6]. The difference between dizziness and true vertigo is that vertigo is a problem within the vestibular system alone, and dizziness can be exclusively visual or a combination of visual and vestibular[2,6].

Maintaining balance requires proper integration of the three afferent sensory systems previously mentioned (i.e. vestibular, visual, and somatosensory) to provide input for the efferent system that consists of multiple neurological pathways[1-2]. The vestibular ocular reflex (VOR) is the bridge that connects these afferent systems to the efferent action of the extraocular muscles (EOMS).

Proper VOR function results in stable bifoveal retinal images; therefore, any uncompensated binocular instability, as often seen in PCS, can lead to symptoms of vestibular dysfunction [1-2]. Oculomotor dysfunctions such as heterophorias, convergence insufficiency, accommodative dysfunction or fixation disparities are secondary to a traumatic brain injury [4-5]. All of these binocular instabilities that were compensated for before a concussion are often intensified post concussion, thus leading to feelings of dizziness, disequilibrium and balance instability[1-2]. A brief overview of the vestibular system, the visual system and the VOR system will follow.

Vestibular system. The vestibular system plays an intrinsic role in balance and maintaining visual and spatial orientation [3]. Like any neurosensory processing, the vestibular system consists of three components; a peripheral sensory mechanism, a central processor and a motor output system[2]. The peripheral sensory mechanism is encased in the semicircular canals of the inner ear. There is one anterior canal, posterior canal, and horizontal canal in each ear. The semicircular canals are disk-like structures that are geometrically configured to sense rotational acceleration of the head and body in all directions of space [1-2].

Central processing of the vestibular system occurs in the vestibular nuclei, located in the cerebellum [2]. The vestibular nuclei complex is where sensory input from the vestibular, visual, and somatosensory systems are combined to maintain balance [2]. The final output occurs through the visual system and the somatosensory system to produce appropriate ocular and postural movements, respectively, to maintain visual stability and balance [2].

Oculomotor system. It is an important reminder that about one-third of the sensory input that contributes to balance and coordination comes from the visual system; therefore, any inconsistent visual input can result in feelings of dizziness or vertigo [2,6]. The oculomotor system orchestrates accommodation and vergence and their simultaneous modifications enable individuals to visualize an object at various distances and directions [4]. Conflicting visual information can result from abnormal eye movements such as nystagmus or decompensated heterophoria, visual field defect, aniesokonia, or any combination of these defects [1-3,6]. Blurred vision, diplopia, suppression difficulty reading, eyestrain, headaches and problems with visual scanning are all sequle to poor oculomotor function [3].

Those patients with intermittent deviations are most often the ones who suffer from post concussion syndrome [2]. One explanation is that pre-concussion compensated phorias are more difficult for the brain to maintain alignment, thus leading to conflicting information between the two eyes before incorporating it with incoming vestibular and somatosensory input [2]. This additional brain power requires a level of concentration and energy to contribute to a process that should otherwise be subconscious. This extra cognitive effort contributes to the confusion experienced during dizziness and imbalance[2]. It has been demonstrated that adults with normally functioning vestibular systems who are experiencing symptoms of vestibular dysfunction actually had binocular dysfunctions of both saccadic and vergence movements [2, 4-5].

Vestibular Ocular Reflex. The vestibular- ocular reflex (VOR) is a fast acting reflex [3]. The geometric configuration of the semi-circular canals in the inner ear parallels the insertion of the EOMs on the eyeballs. The foundation of the VOR is a three-neuron pathway that connects each semi-circular canal to one ipsilateral and one contralateral EOM [1]. This organized relationship between the semi-circular canals and the EOMs allows for neural input from the vestibular system to stimulate neural output of the EOMs in an equal and opposite manner to maintain a clear and stable image on the retina during movement [1-3].

The breakdown of binocularity increases the discrepancy between the visual and vestibular inputs that affects the VOR and sense of balance. VOR impairment can manifest through nystagmus, oscillopsia, photosensitivity, and/or sensitivity to flickering light that can occur with fluorescent lights [2]. Sensitivity to fluorescent lights is very common in those suffering from PCS [2]. A combination of fluorescent light sensitivity, sensitivity to movement, and decreased peripheral awareness can make shopping, or being in crowds a daunting task [2-3]. Especially because the peripheral vision system is a major contributor to vestibular integration and yields contrast sensitivity, detection of movement, supports posture, balance, and spatial orientation [2]. Recent research has led to a better understanding of the relationship between central and peripheral visual processing, and central and peripheral vestibular processing [1]. These advances in study are the foundation to improving vestibular/visual rehabilitation and reestablishing balance [1].

Procedures

The main goals of optometric vision therapy in vestibular dysfunction is to first, enhance the stability of the visual system with an accurate refraction. Then, stabilize fixation, improve motor control and planning and enhance peripheral awareness. Followed by, developing a stable binocular system to include accommodation and vergence flexibility, facility of vergence, and central fusional vergence stability. Then finally, re-establish the stability of the binocular system in a dynamic visual environment, incorporating head and body movement while increasing somatosensory cues [2].

Gaze Stabilization. To re-establish the VOR response, activities designed to induce movement of a visual image on the retina, or retinal slip, is effective. Retinal slip is the feedback error that drives adaptation of the VOR and should be made clear to the patient in the instructions of such activities [3]. Exercises where the patient is maintaining fixation while moving their head is most beneficial, and can be altered by varying target size, postures, duration, direction, amplitude and velocity [3].

To start, place a single letter fixation target at the patient's eye level (i.e. X). Explain to the patient that they must keep the letter clear, single and stable, as they turn their head side- to-side as if to say "no". Increase the speed as ability increases. Introduce the vertical directions (i.e. as if to say yes) and the diagonals in the same manner. Start each exercise monocular first, then proceed to binocular fixation. Once the single letter is mastered, increase the number of letters to keep clear by making the target a word, or miniature Hart Chart to load the visual stimulus. An increase in peripheral awareness is vital to successful rehabilitation post concussion. Patients in recovery tend to rely on central processing to maintain fusion when in fact expanding peripheral awareness and attaining fusion through softer viewing is more beneficial in increase flexibility and accuracy of vergence eye movements [7]. Accurate oculomotor skills are the foundation of stabilized visual input during movement.

To increase peripheral awareness with this activity, have the patient place hands shoulder width apart on either side of the target. The patient is asked to maintain a clear target while moving their head but also notice both hands simultaneously. Hands also add tactile feed back to make the patient feel more stable. The patient should spread their hands farther apart to increase peripheral awareness, but also get to a place where they are not dependent on their hands for stability.

Other ways to maintain a steady gaze and peripheral awareness is to do this exercise in front of the mirror with the fixation point being an accommodative target, or the reflection of the patient's eye. Now the patient must maintain eye contact with their reflection while noticing the background movement. Or with the same instructions, use a handheld chart moving in the opposite direction as the head, all the while maintaining a steady gaze but being aware of the background [3]. Other optical modifications include low plus, base in prism, or binasal occlusion. These optical modifications are all ways to increase peripheral awareness.

Incorporating other sensory systems can be done by having the patient place their hands on their neck to increase body awareness and stimulate cervical proprioception that is necessary for posture and stability. Having the patient wear a scarf, hooded sweatshirt or putting a towel around the patient's neck can provide the same support.

Infinity Walk. The infinity walk was developed by clinical psychotherapist Dr. Deborah Sunbeck in the mid-1980s and has since been adopted not only by optomotrists and vision therapists, but also occupational therapists and other neurorehabiliation specialists [8]. This exercise is an effective way to integrate the whole body into the visual system, as the foundation for binocularity is efficient use of both sides of the body [8].

To start, place a letter chart on the wall at the patient's eye level. Two obstacles (e.g. stools, chairs, etc) should be placed about four feet away from each other, about five feet from the wall with the chart on it. The chart should be the midline between the obstacles. The patient is instructed to walk around each obstacle in the shape of an infinity sign while maintaining a clear single image of the lettter chart. The patient is then asked to call out the letters on the chart row by row to the beat of a metronome set to 1 beat per second (60 beats per minute). This should be performed in both directions.

There is a lot of freedom to be creative in involving different sensory systems and levels of cognition to this activity. More complex eye movements can be incorporated by reading down the columns, reading the rows (or columns) starting from the exteriors of the chart working toward the interiors, or using multiple charts. To increase cognitive demand arrow charts could be used instead of letters. Having the patient first call out the direction that the arrows are pointing in to eventually being able to call out the opposite direction that the arrows are pointing. All while maintaining the infinity movement. Optical devices like low plus or tints can be used to increase optical demands.

By requiring the patient to switch directions of walking with an auditory command like clapping or snapping is also an advanced skill. The more sensory systems involved in this activity the more beneficial this exercise can be. Especially for patients who are hypersensitive to busy grocery stores or malls.

Front/ Back Fixations. The purpose of this exercise is to develop body laterality, eye-hand coordination, rhythm and visual/vestibular integration. This is another activity that can be utilized by other neurorehablitative specialists to improve vestibular symptoms. Starting with a single target fixation point (i.e.a letter target) on opposing walls of a room, at the patient's eye level, the patient should stand in the center of the room between the targets. The patient begins facing one of the targets with both arms by their sides. The following sequence should be followed: right hand at the front target, right hand at the floor, right hand at the rear (across the body and over the left shoulder), both hands at the floor, left hand at the front, left hand at the floor, left hand at the rear (across the body and over the right shoulder), both hands at the floor, etc. The goal is for the patient to complete each action without overshooting or undershooting and only moving the hand indicated.

Sensory loading can occur through use of a metronome to provide a rhythm for movement, adding the use of a letter chart or arrow charts for visual and cognitive challenge. The visual demand can also be increased by adding vectograms or tranyglyphs, to challenge convergence and divergence skill that are required to grasp fixation as well as fusion while maintaining movement.

Optical Devices. Treatment and management of PCS starts with a careful refraction. Small refractive changes can be perceived as large changes in magnification. Even mild minification, as caused by minus lenses, can increase motion sensitivity in post concussion patients, whereas low plus lenses increase VOR gain secondary to magnification and decrease hypersensitivity to motion [7].

Other optical devices such as yoked prism or binasal occlusion are often effective in decreasing symptoms. Yoked prism can be prescribed temporarily to compensate for any vertical diplopia, gaze restriction or visual field defects [1,9]. Yoked prism is also commonly used during therapy as a tool to enhance perceptual processing deficits and generate sensory disruption to which the patient has to adapt to maintain balance [1-2]. Similarly, binasal occlusion is another option that helps those suffering from vestibular symptoms by improving the organization of peripheral processing to promote binocularity [9].

Light sensitivity is a common symptom that persists post concussion. Tints decrease contrast to alleviate symptoms [7]. For outdoor use, brown and gray polarized lenses are effective and for hypersensitivity to fluorescent lights a bluish-purple tint (e.g. Omega by BPI) are most effective [9]. The use of blue tint may enhance magnocellular processing, resulting in the patient feeling "more grounded" in space [1].

Conclusion

The integration of multisensory information utilizes an inhibitory-reciprocal process that is evident in the normal functioning vestibular-ocular reflex system, in which activation of vestibular pathways result in inhibition in visual pathways and vice-versa [1]. This inhibitory-reciprocal process malfunctions following a traumatic injury to the brain. The traumatized brain loses its capacity to integrate sensory information from the visual, vestibular and somatosensory systems. This inability to resolve conflicting information results in dizziness, disequilibrium and balance instability [1-2].

Due to the intimate relationship between the visual and vestibular system, it is possible for vestibular symptoms to be visual in nature, but also vestibular dysfunction to have a large visual component [2]. Thus, both populations can benefit from optometric vision therapy and/or optical devices to alleviate symptoms.

Patient's recovering from a brain injury may lack phoria adaptation, but neuro-optometric vision therapy will increase accommodative function and convergence through the use of lenses, prism and other optical devices [2]. Therapy also leads to improvement in balance between central and peripheral processing systems, as well as an improvement in VOR gain with improved accommodative ability and visual skills [2]. During therapy, providing activities that have unusual visual stimulus along with vestibular and somatosensory information creates sensory conflict and forces the patient to "choose" a single system for balance which leads to desensitization to visual surround movement [2].

Post concussion syndrome involves multiple systems and should be treated accordingly, calling on an integrative approach between vestibular physical therapists, occupational therapists, and optometric vision therapy [1-3,6]. Rehabilitative optometric vision therapy along with neuro-physical therapy or occupational therapy leads to successful improvement of the VOR system and fewer incidents of dizziness and imbalance.

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