Overview of Vergence

Vergence is one of three components that comprise the oculomotor system, which also includes version and accommodation. In vergence, both eyes rotate around a vertical axis in opposite directions to obtain a single, fused binocular vision for images of varying depths. 1 The eye movements must be accurate to avoid diplopia. In other words, if one extrinsic muscle is weaker than the other, the viewed image will be projected to different parts of the retina causing the brain to see two images. 2 There are some basic terms that apply to vergence. Convergence refers to the ability of the eyes to move and function together. 3 This simultaneous inward motion, facilitated by the medial rectus muscle, allows the eyes to focus on an image that is closer in depth to the individual. 4 Conversely, divergence refers to the simultaneous outward movement of the eyes away from each other. The lateral rectus muscle facilitates this motion. 4 Fusion refers to the ability to use both eyes together. 3An individual’s two eyes view two slightly different images at any one time. Fusional vergence is the process by which these slightly different images are fused together to form a single image. 5

Vergence Dysfunction and Mild Traumatic Brain Injury (mTBI)

Ciuffreda et al reported that 90% of individuals with mTBI and presenting with vision-related symptoms were found to have oculomotor dysfunction. Convergence insufficiency, a type of vergence dysfunction, was the most common. 6 Thiagarajan et al reported vergence dysfunction in 24-48% of subjects post-mTBI in several military and Veterans Affairs studies. 7 Neurons discharge in various areas all over the brain during vergence activity. These areas include the midbrain, pons, cerebellum, and areas of the cerebral cortex (e.g. parietal lobes). 8 The sheer number of locations for these neurons creates complicated neural pathways, so it stands to reason that an injury such as mTBI might adversely affect them. 7

Clinical Presentation and Examination

Clinical presentation for vergence dysfunction will include blurred vision, diplopia, discomfort or a pulling sensation around the eyes after a near vision task (e.g. reading), general fatigue, and motion sensitivity. 9,10 Convergence insufficiency occurs when there is exotropia and the exodeviation is greater at near than far distance. 11 So, when an individual’s eyes adduct to maintain focus on a near distance image, one eye can only maintain that adduction and focus to a point. Then, it will abduct slightly causing the retinal image to be different from that on the opposite eye.

Ciuffreda et al propose that there are several essential ocular exam components to assess vergence eye movements. These include accommodative vergence/accommodation ratio, fusional vergence ranges for near and far distances, phorias at near and far distances, vergence facility, and near point of convergence. The authors note that this is not an all-inclusive list, and the clinical guidelines published by the American Optometric Association for the treatment of vergence dysfunction suggest several additional tests for the clinician. 2,12 These include visual acuity and fixation disparity. 2

This paper will focus on fusional vergence, vergence facility, and near point of convergence because they are fairly simple exam components and can be tested without highly specialized equipment. Fusional vergence refers to the amount of prism a patient can tolerate in front of both eyes before the patient reports blurriness. Fusional vergence at a distance is tested the same manner, with the exception that the visual target is placed 20 feet from the patient. Vergence facility is tested with prism flippers and measures how quickly the eyes can adjust when subjected to change between a converging and diverging position. Lastly, near point of convergence is tested by slowly bringing an eye-level object (e.g. pen tip) close to the patient’s nose and documenting when the patient reports seeing double or one eye becomes exophoric. 2 This should begin at 50 centimeters in front of the patient. Normal values are ≤7.5 centimeters for initial reported diplopia and ≤10.5 centimeters for recovery of a single, fused image. 13 Near point of convergence is an assessment of binocular vision and should be performed several times. Two markers that can indicate convergence insufficiency are a receded near point of convergence and a reduced fusional convergence. 2

The Convergence Insufficiency Symptom Survey (CISS) is a reliable and valid outcome frequently reported in the relevant literature. It is comprised of 15 questions that focus on symptoms an individual might experience with reading and other near distance work. Unfortunately, the CISS is not efficient at detecting patients with few but severe symptoms. For example, it will best alert a clinician to a symptomatic patient who has multiple mild to severe symptoms, but it will not be as reliable for a patient who has constant diplopia but not other symptoms. 2

Vision Therapy

Ciuffreda et al propose that the main purpose of general vision therapy is to improve the speed and accuracy of oculomotor functions so that an individual can achieve clear, fused, and symptom-free binocular vision for extended periods of time. 9 The clinical guidelines published by the American Optometric Association for the treatment of vergence dysfunction indicate that vision therapy for convergence insufficiency has an excellent prognosis. The guidelines recommend 12 to 20 follow-up visits after initial examination in addition to a supplemental home program and prisms if necessary. Similarly, the guidelines recommend 15 to 20 follow-up visits for fusional vergence dysfunction with an excellent prognosis. 2

Kapoor et al suggest several treatment goals for vision therapy with vergence dysfunction. The first is to achieve “fusional reserves” for near and far distances and the second is to maintain binocular viewing for 20 minutes at a time without symptoms. 10 Fusional reserves refer to the ability of the eyes to maintain a single, fused image binocularly while under strain. 13 The same authors describe a general protocol for treatment of vergence dysfunction. All exercises should be performed at both near and far distances. The provider should increase the convergence demand on a patient until the patient reports diplopia, then the provider should decrease the convergence demand by pulling the test object away from the patient until the patient reports seeing a single object. This should be repeated for a total of five times and followed with the same protocol but with increasing divergence demand. This is known as “ramp training” and should be followed by “step vergence”. “Step vergence” involves quickly alternating the vergence demand on a patient, beginning with small increments of distance and progressing to larger increments. 10

There are many other treatment methods for convergence insufficiency and for training fusional vergence. One method for training convergence insufficiency is a Brock string, which is one string with three beads on it. One end is fixed to a wall or doorknob, while the other is held at the tip of the nose. The beads are spaced out along the string, and the patient must focus on fusing the image of one bead at a time until the image appears as a single bead. The patient will begin with the closest bead and advance to farther beads as the patient’s binocular vision is improved. 14 A method for training fusional vergence is with a fusion trainer. This displays two slightly different images that must be fused into one image by the patient. 5 Furthermore, handheld prisms are frequently used in vergence training such as with the Brock string. It is important to note that use of large magnitude prisms (10 prism diopters or more) can lead to nausea and disorientation with patients diagnosed with vestibular dysfunction. 10

Implications for Clinical Practice

Visual deficits (e.g. convergence insufficiency) can be present in the sub-acute stage following mTBI, even if the patient is not reporting other symptoms. 15 This information is particularly useful in order to target these unreported symptoms. Individuals may be unaware that symptoms are attributable to mTBI, or unaware that there are issues present at all. Knowledge of vision deficits may prompt further exam from other disciplines and facilitate recovery for an individual. Furthermore, a comprehensive visual exam may help with return to duty decisions in military personnel. Components of a vision exam may be performed by a physical therapist during a vestibular exam; however, an optometrist is the ideal healthcare practitioner to perform a comprehensive vision exam. 2 Vision therapy is frequently conducted in occupational therapy.

Physical therapists have the ability to treat patients for vestibular and/or musculoskeletal issues following mTBI. Vision therapy can improve progress in other rehabilitation efforts, such as physical therapy, for the patient who does report additional, non-vision symptoms. 7 Furthermore, Doble et al describe hyperphoria, a condition that is occasionally found in TBI patients. Hyperphoria causes a vertical misalignment in the eyes, which causes the individual to extend his neck in order to see clearly. 16 This can cause vertigo in individuals with vestibular dysfunction and lead to balance issues that will affect physical therapy. Physical therapists should be aware of patients who are concomitantly undergoing vision therapy, with the expectation that these patients may not be able to fully participate in the typical physical therapy session secondary to symptoms from visual deficits. A physical therapist can help alleviate or prevent these symptoms by treating patients in a darker room if the patient has photophobia, or by planning for frequent rest breaks to minimize strain on the visual system.

The present literature regarding vergence is fairly homogenous in that oculomotor deficits are frequently found in individuals post-mTBI. These individuals often present with convergence insufficiency and fusional vergence deficits that lead to diplopia, blurred vision, eye strain, and general fatigue. Vision therapy is reported as beneficial for these individuals and can help improve visual deficits as well as facilitate improvements in other aspects of an individual’s rehabilitation.

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