Outcome Measures and Treatment for Mild Balance Deficits with Vestibular Complaints After Mild Brain Injury

Introduction

Concussion and mild Traumatic Brain Injury (mTBI) have become increasingly popular in the 21st century secondary to concerns about the potential long-term impact of head injury.[1] A concussion is a type of mTBI caused by a blow to the head or body that transmits impulsive forces to the head[2] causing the brain to undergo an acceleration-deceleration moment which as a result, induces physiological disruption of brain function.[1] Moreover, the terms concussion and mTBI are synonymous and can be used interchangeably. Signs and symptoms of concussion include headache, dizziness, gait unsteadiness, slowed reaction times, visual changes, and drowsiness.[2,3] While most athletes recover from a sports-related concussion (SRC) within 7-10 days, approximately 10-30% present with persistent post-concussive symptoms.[4] Similarly, other sources say typical full recovery from a mTBI occurs in less than 3 months, with 10-20% of people exhibiting persistent symptoms.[3] These post-concussive symptoms are frustrating for the patient as they often limit their return to activity and cause persistent disability. Dizziness, unsteadiness, and blurred vision are common patient complaints after sustaining a mTBI and have been increasingly utilized as signs that return to play or duty should be limited until resolution.[3] These deficits can be related to problems arising in the vestibular system as a result of benign paroxysmal positional vertigo (BBPV) or unilateral vestibular hypofunction (UVH), migraine headaches, visual dysfunction, and spatial disorientation.[3,5] The purpose of the rest of this paper is to address appropriate outcome measures and interventions for patients experiencing post-concussive symptoms, with a focus on patients experiencing balance and vestibular deficits.

Subjective Outcome Measures for Balance and Postural Instability

Weightman et al. contends that there are a multitude of both subjective and objective outcome measures to use with patients complaining of balance deficits following mTBI and recommends measures that evaluate high-level mobility, gait, gross strength, and confidence in balance.[3] One subjective measure that has been used with many patients with post-concussive symptoms is the Dizziness Handicap Inventory (DHI).[3,5-7] The DHI contains 25 questions assessing physical, emotional, and functional disability related to dizziness with higher scores

indicating greater impairment.[7] Scores on the DHI can also help classify severity of impairments with scores ranging from 0-39 indicating mild impairment, 40-69 moderate impairment, and 70-100 severe impairment.[7] The instrument also includes notes at the bottom that look at responses to 4 of the questions that can be helpful to determine the presence of BPPV.[3] In an earlier study by Gottshall et al, the DHI demonstrated concurrent validity with dynamic visual acuity testing (DVAT) in 53 active duty patients with mTBI.[8] However, the authors noted that this relationship diminished after one week likely due to the fact that the DHI assesses domains such as depression, anxiety, and relationships compared to DVAT.[8] This is a potential benefit of the DHI in that it can capture the emotional effects of dizziness that objective measures can't. Furthermore, the DHI takes little time to complete, and comes recommended by the TBI EDGE for use in outpatient settings and highly recommended by the vestibular EDGE for patients with vestibular dysfunction (i.e. BPPV).[9] Another self-report measure that could be useful in determining a patient's confidence in their balance with various activities is the Activities-specific Balance Confidence scale (ABC scale).[3,5,10,11] In a 2010 retrospective chart review of 114 patients, the ABC scale was used to illustrate progress made in vestibular rehab following concussion.[11] In this study, the ABC scale demonstrated statistically significant changes in scores at the end of treatment[11] highlighting its utility for patients with post-concussive symptoms and vestibular complaints. The post-concussion symptom scale (PCSS) is another self-reported measure that can be used to detect concussion in the acute phase as well as to track recovery and response to treatment.[12-15] The PCSS is very quick to administer and includes information from multiple domains (i.e. sleep patterns, concentration, light sensitivity, etc.),[15] and thus, may be useful in evaluating the effect of treatment on those symptoms.

Objective Outcome Measures for Balance and Postural Instability

The High-level Mobility Assessment Tool (HiMAT) is a valid, reliable, and responsive performance measure that can be used in patients with mTBI to assess balance and mobility.[16] It consists of gait speed, running, skipping, hopping, and stair test items that are either timed or measured with a tape measurer.[16] In 2013 cohort study, the HiMAT was administered to 92 patients with a mTBI at 3 and 6 months post injury and demonstrated a large correlation ($r=0.63$, $p<0.001$) between Rivermead post-concussion symptoms questionnaire.[16] However, it's important to note that there was a ceiling effect observed in 22.8% of patients that was related to

the items that involved stairs.[16] Additionally, this measure does not explicitly address the contribution of vestibular dysfunction and therefore, the use of additional objective balance measures is warranted. The Functional Gait Assessment (FGA) is another appropriate outcome measure that is commonly used in patients with vestibular disorders.[6,10] The test was developed to reduce the ceiling effects of Dynamic Gait Index and is composed of 10 items which require different speeds of walking with vertical and horizontal head turns, eyes closed, with a narrow base of support, and backwards ambulation.[5,10,17] In an older study by Wrisley et al,[17] the FGA was administered to 6 patients undergoing vestibular rehabilitation and demonstrated moderate correlation with the DHI, ABC scale, and the original DGI. However, a 2014 study[18] demonstrated similar FGA scores in the 50th and 95th percentiles for 91 healthy high school-age adolescents—clinicians should be aware of these ceiling effects when working with younger patients. Nonetheless, the FGA is likely more sensitive to vestibular dysfunction than the HiMAT due to testing of conditions involving head turns, eyes closed, and narrow base of support. Therefore, the FGA may be a better option if there isn't time to administer both tests.

A measure of static balance would also be useful in quantifying postural instability in a patient post-concussion. The balance error scoring system (BESS) requires the patient to stand with feet close together, tandem, and single-leg stance on both firm and foam surfaces with eyes closed for a maximum of 20 seconds.[10] Patients accrue error points for eye opening, lifting hands off the hips, stepping, or letting either the heel or foot come of the surface for a maximum of 10 errors in each 20 second trial.[10] Higher scores on the BESS indicate worse balance. While the BESS is easily administered in <5 minutes, some report issues with a practice effect observed with repeated testing as well as issues with reliability, given the subjective nature of the outcome measure.[10] King et al.[19] sought to reduce the subjective nature of the BESS by adding inertial sensors during administration. They found that while scores from instrumented and non-instrumented scores were similar, that the instrumented conditions were diagnostically superior.[19] However, it's important to note that the sensitivity for bot instrumented and non-instrumented didn't exceed 54%,[19] lending some concern for the ability of the BESS to capture subtle balance deficits that may be present in a patient with post-concussive symptoms. An alternative to the BESS, is the modified clinical test of sensory interaction on balance (mCTSIB) which is similar to the BESS except it uses both eyes open and eyes closed conditions and has been shown to be sensitive to patients with vestibular dysfunction.[10] Similar to the BESS, there is

concern for the subjective nature of the test and its ability to detect change over time, thus, recent research has explored portable inertial sensors with the mCTSIB, with promising results.[20] However, even without sensors, the BESS and mCTSIB may provide valuable information and may have the most clinical utility given the quick administration time and equipment needs.

Assessment of Vestibular and Oculomotor function

It's important to briefly discuss assessment of vestibular and oculomotor functioning before exploring treatment to better understand the efficacy of treatment. The vestibular system detects motion of the head in space and helps to regulate both postural stability and integration of head and eye movements.[21] Oculomotor function is complex, involving pursuits and saccades, vergence, and visual-fixation movements that work with the vestibular system to maintain stability of the visual system.[21] An assessment tool such as the Vestibular/Ocular Motor Screening tool (VOMS) can be used with the other previously mentioned outcome measures to help identify deficits in vestibular and oculomotor functioning that can occur with head injury.[12,21] The VOMS tool looks at symptom provocation headache, dizziness, nausea, and fogginess) with testing of smooth pursuits, horizontal and vertical saccades, convergence, horizontal and vertical Vestibulo-ocular reflex (VOR), and visual motion sensitivity.[21] Mucha et al. administered the VOMS to 64 adolescent patients <2 weeks post-concussion and identified that the VOMS was able to discriminate those who had concussions and those who didn't quite well (AUC = 0.89).[12] The VOMS has also been used in patients with chronic mTBI undergoing individualized vestibular rehabilitation and showed statistically significant changes in scores after treatment,[13] further supporting the use of this measure to assess patients with mild brain injury.

Treatment Activities

Multiple authors[5,6,11,13,16,21] have lent support for vestibular rehabilitation exercises after mTBI. Schneider et al. evaluated the effects of vestibular and cervical spine physical therapy in patients with persistent post-concussive symptoms.[5] The vestibular rehabilitation portion of the intervention included habituation, gaze stabilization, adaptation, standing and dynamic balance exercises in addition to canalith repositioning maneuvers.[5] After 8 weeks, 73.3% of the individuals in the treatment group were cleared to return to sport whereas only 7.1% of those in

the control (graded exertion only) were cleared.[5] Alsalaheen et al.[11] found that VORx1, standing balance under different conditions, walking with head turns, and canalith repositioning maneuvers were the most common exercise prescribed for adolescents undergoing vestibular rehabilitation after a concussion. In this study, patients reported dizziness as a symptom of being off balance, lightheadedness, spinning, nausea, and sensation of motion.[11] Participants were treated for a median of 4 visits over 33 days, and demonstrated improved dizziness severity, DHI scores, FGA scores, and ABC Scale scores, and gait speed at the end of treatment ($p<0.001$).[11] Storey et al[22] found significant improvements in level of performance on the BESS ($p<0.0001$) in pediatric patients who were referred to vestibular rehab. Furthermore, the interventions consisted of habituation and adaptation to improve coordination and gaze stability[22] consistent with other studies' descriptions of vestibular exercises. Despite the apparent support for vestibular rehab in patients with mTBI or concussion, a 2017 systematic review[23] revealed that the overall quality of the literature supporting vestibular rehab in this group is low, lending to high risk of bias in the included studies. One limitation the authors found was poor reporting of exercise prescription and progression[23] which is probably related to the individualized nature of treatment. Nonetheless, there is emerging evidence for vestibular rehabilitation in patient's post-concussion.[23] Three studies[5,22,24] included in this paper provided descriptions of exercises and treatment activities in vestibular rehab for concussed patients.

Examples of treatment activities that should be in a vestibular rehabilitation program include gaze stabilization exercises, where the patient is required to look at a target while moving the head in different directions and at different speeds to improve the VOR.[5,6] Alsalaheen et al.[24] found that eye-head coordination exercises (i.e. VORx1, convergence, smooth pursuits, etc.) were the most commonly prescribed exercises in a HEP for pediatric concussion patients. The most commonly prescribed exercises in this category were VORx1, VORx2, VOR cancellation, and convergence.[24] In general, the trend was to start the exercises in quiet sitting or standing and progress to narrow bases of support and finally, walking. Habituation exercises include repetitive motions in a direction that exacerbates dizziness followed by a rest period to allow symptoms to resolve[5] and can be used to reduce visual motion sensitivity over time.[20] Convergence can be trained using beads on a string or pencil puships.[22] With pencil pushups, the pencil is held at arms-length and the letters are kept in focus as the pencil is brought closer to the face with the goal for trying to prevent the letters from getting blurry as long as possible.[22] Smooth pursuits

can be performed by follow a moving target with the eyes[5] and saccadic eye movements can be performed by looking back and forth between 2 post-it notes.[22] Lastly, another exercise that can be performed to improve cervical proprioception is the cervicocephalic kinesthetic awareness exercise.[5] A headband with a laser is placed on the forehead and the patient moves their head back to their perception of neutral with their eyes closed.[5] All of the aforementioned exercises target eye-head coordination and can be a vital part of restoring vestibular function in patients with gaze stability deficits and UVH.[3]

Static balance exercises are also commonly prescribed and typically progress from static standing with weight shifting, to standing on one leg, to standing on a rocker board, or sit to stands.[24] Dynamic balance exercises could include walking with head turns, walking while changing speed or direction, carioca, and other dual task ambulation exercises such as tossing a ball against the wall while walking.[5,22,24] Static balance exercises typically proceed dynamic or ambulation tasks as the patient is often symptomatic during the initial evaluation. It's important that these static and dynamic balance exercises be gradually progressed to approximate demands of the person's work, sport, or ADLs. As a general principle, each system that contributes to balance should be challenged (visual, somatosensory, vestibular) starting with one targeted system and progressing to challenge all of the systems.[14] Brown et al. contends that dual-task exercises combining motor and cognitive aspects may mimic real world situations.[14,25] A 2013 systematic review found that dual task exercises had greater response times, gait and postural control deficits in concussed patients.[25] They further report that some dual task exercises were better able to exploit mild balance deficits following a concussion.[25] This further highlights the need to go beyond typical exercise prescription and devise treatments that are specific to what the patient will encounter.

Last but not least, it's important to consider that episodic dizziness can occur as a result of BPPV, where the forces imposed on the brain can cause the otoconia to be displaced.[14] Brown et al. reports that due to the forceful nature of head injuries, there may be more than one canal involved and thus treatment can take more sessions to resolve compared to the normal profile of BPPV.[14] Posterior and horizontal canal BPPV can be identified with the Dix-Hallpike and Roll maneuver, and treated with the modified Epley maneuver and the barbecue roll maneuver, respectively.[3.14]

Summary

This paper has identified multiple outcome measures (DHI, ABC scale, PCSS, HiMAT, FGA, BESS, mCTSIB, VOMS) that could be useful when used with patients that have mild balance deficits with vestibular dysfunction after a mTBI or concussion. One additional measure that was not included but came up consistently in the literature was the Neck Disability Index (NDI),[5] which may be useful in patients with concurrent cervical spine complaints. Additionally, this paper has identified multiple interventions for patients with post-concussive symptoms, although the list is not exhaustive. In general, treatments should be based on impairments noted in the examination. For example, findings on both the FGA and the VOMS could indicate dizziness with horizontal head turns, suggesting issues with the VOR. Therefore, VORx1 can be performed sitting in a quiet environment as part of an initial exercise program. Interventions should target eye-head movements, static, and dynamic balance. Overall, there is evidence to support the efficacy of including targeted vestibular interventions in the rehab of patients with mild balance deficits after a concussion.

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