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# Vestibular rehabilitation after mild traumatic brain injury with vestibular pathology

Kim Gottshall
*Director of Vestibular Assessment and Rehabilitation, 34520 Bob Wilson Drive, San Diego, CA, USA*
*Tel.: +1 619 532 7450; Fax: +1 619 532 5032; E-mail: Kim.gottshall@med.navy.mil*

**Abstract**. Vestibular complaints are the most frequent sequelae of mTBI. Vestibular physical therapy has been established as the most important treatment modality for this group of patients. Nevertheless there is little work objectively documenting the impact of vestibular physical therapy on this group of patients. Studies have been completed in the past examining clinical measures like the GCS on overall recovery pattern after TBI. But outcomes measures specifically aimed at examining the adequacy of vestibular tests to track vestibular recoveryhave remained lacking. Scherer and Schubert reinforced the need for best practice vestibular assessment for formulation of appropriate vestibular physical therapy treatment strategies. Now the application of vestibular testing and rehabilitation in this patient population is needed to provide information on objective outcome measures. Vestibular physical therapy is most effective when applied in a customized fashion. While we and others have developed vestibular physical therapy procedures that are applied in best practices for mTBI vestibular patients, these therapies must be customized for the patient entry level of function and expectation level of recovery. Knowledge of the patient's disability and diagnosis is critical to build the foundation for return to activity, work, or sport.

Keywords: Vestibular, physical therapy, mild traumatic brain injury

## 1. Vestibular traumatic brain injury with vestibular pathology

Vestibular pathology after mild traumatic brain injury (mTBI) is a common disorder that is characterized by unsteadiness and dizziness [11]. Work in our lab has been able to characterize types of balance disorders seen after mTBI. Blunt mTBI can produced positional dizziness, migraine associated dizziness, exercise induced dizziness, spatial disorientation may occur (Table 1).

Whereas, blast mTBI associated symptoms of positional dizziness, exercise induced dizziness, spatial disorientation and spatial disorientation with episodic vertigo plus fluctuating hearing loss, tinnitus, and ear pressure may also occur. (Table 2).

Spatial disorientation occurs much more frequently in the blast mTBI population, than the blunt mTBI population (Fig. 1) While a great deal of work has focused on these symptoms [8,10,20], little attention has been directed at other vestibular assessment and vestibular rehabilitation with mild traumatic brain injury (TBI) from blunt or blast head trauma [3,4]. These are symptoms that have been shown to respond to vestibular physical therapy intervention in other disorders [7]. However, little work has been done documenting the use of vestibular physical therapy for dizziness and unsteadiness except for its use after nerve section, labyrinthectomy, or gentamicin [5,16]. Recent trends in TBI treatment have been directed at medication to control headaches and intermittent vertigo attacks. It is important to reevaluate the role of rehabilitation in the context of these new treatment paradigms. The effect of vestibular physical therapy intervention on the symptoms of unsteadiness and disequilibrium associated with blunt and blast mTBI is most effective in patients that have episodic headaches and vertigo controlled [6].

## 2. Vestibular assessment

Patients presenting to our tertiary care center with mTBI undergo a history and standardized physical examination by a team of a neurotologist and a physical therapist, as well as a complete auditory-vestibular

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Table 1
Blunt mTBI Induced Dizziness

| Entity | History | Physical exam | Vestibular tests |
|---|---|---|---|
| Positional Vertigo | Positional Vertigo | Nystagmus on Dix-Hallpike test or modified Dix-Hallpike test | No other abnormalities |
| Exertional Dizziness | Dizziness during and right after exercise | Abnormalities in challenged gait testing | No other abnormalities |
| Migraine Associated Dizziness | – Episodic Vertigo with periods of unsteadiness<br>– Headaches | – Abnormalities in challenged gait testing<br>– +/– Abnormalities on head impulse testing<br>– Normal static posture tests | – VOR gain, phase, or symmetry abnormalities<br>– High frequency VOR abnormalities<br>– Normal posturography |
| Spatial Disorientation | – Constant feeling of unsteadiness worsened by standing but still present when sitting or lying down<br>– Drifting to one side while walking<br>– Shifting weight when standing still | – Abnormalities on standard gait tests<br>– +/– Abnormalities on head impulse testing<br>– Abnormalities on static posture tests | – VOR gain, phase, or symmetry abnormalities<br>– High frequency VOR abnormalities<br>– Abnormal posturography<br>– Central findings on rotation chair testing |

Table 2
Blast mTBI induced dizziness

| Entity | History | Physical exam | Vestibular tests |
|---|---|---|---|
| Positional Vertigo | Positional Vertigo | Nystagmus on Dix-Hallpike test or modified Dix-Hallpike test | No other abnormalities |
| Exertional Dizziness | Dizziness during exercise | Abnormalities in challenged gait test | No other abnormalities |
| Blast induced Disequilibrium | – Constant feeling of unsteadiness when standing and waling worse with challenging environment<br>– Constant Headache | – Abnormalities in challenged gait<br>– Abnormalities in tandem Romberg<br>– Abnormalities with quick head motion | – Abnormal posturography<br>– Abnormal target acquisition, dynamic visual acuity, and gaze stabilization<br>– +/– VOR gain, phase, or symmetry abnormalities |
| Blast induced Disequilibrium with Vertigo | – Constant feeling of unsteadiness when standing and waling worse with challenging environment<br>– Constant Headache<br>– Episodic Vertigo | – Abnormalities in challenged gait<br>– Abnormalities in tandem Romberg<br>– Abnormalities with quick head motion | – Abnormal posturography<br>– Abnormal target acquisition, dynamic visual acuity, and gaze stabilization<br>– VOR gain, phase, or symmetry abnormalities |

test battery, rotational chair testing (Neurokinetic), and MRI imaging as indicated. The objective assessment of mTBI patients by the vestibular physical therapist includes a computerized dynamic posturography (CDP) (Neurocom Inc, Clackamas OR) Sensory Organization Test (SOT), Motor Control Test (MCT) and Adaptation Test [15]. Also performed, is a computerized In-vision tunnel testing of perception time, saccades, target following, dynamic visual acuity, and gaze stabilization (Neurocom Inc, Clackamas, OR) [4]. The patients additionally, undergo a clinical vestibular function test battery consisting of an impulse head thrust test, headshake test, Fukuda step test, Romberg test, tandem Romberg test, and three standard cerebellar tests. A Fuctional Gait Assessment (FGA) is administered to each patient to assess dynamic gait [22]. In addition, the Dizziness Handicapped Index (DHI) [12], Activities-Specific Balance Confidence Scale (ABC) [18], Vestibular Rehabilitation Benefits Questionnaire [14] and surveys are administered. The above measurements are obtained pre-treatment, during treatment, and post-treatment (6–8 weeks after beginning treatment). Subjective patient reports of degree and length of imbalance perception are docu-

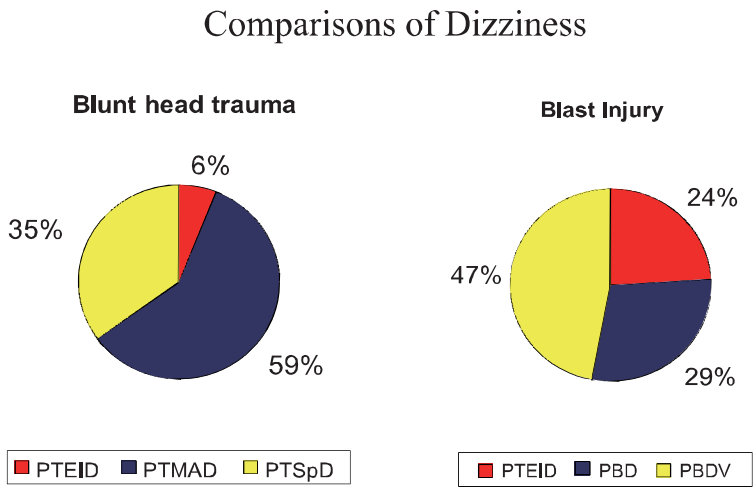


Fig. 1. Comparison of Dizziness in m TBI after Blunt Head Trauma and Blast Head Trauma. PTEID = Post-traumatic Exercise Induced Dizziness. PTMAD = Post-traumatic Migraine Associated Dizziness. PTSpD = Post-traumatic Spatial Disorientation. PBD = Post-blast Dizziness. PBDV = Post-blast Dizziness with Vertigo.

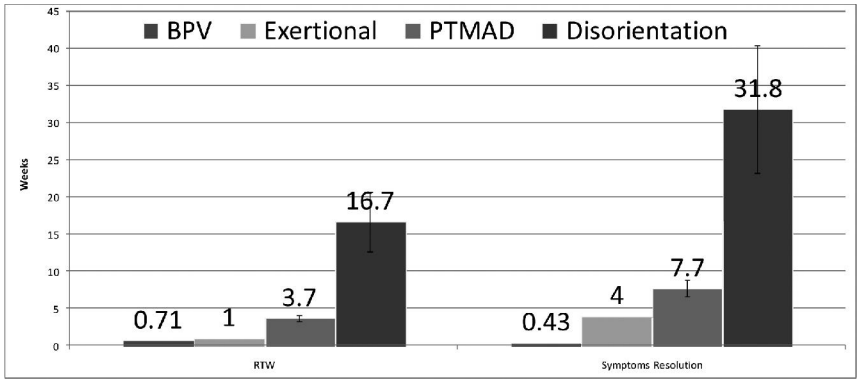


Fig. 2. Return to work (RTW) and Symptoms Resolution in weeks of vestibular physical therapy treatment for patients with the four different diagnostic dizziness conditions seen in blunt mTBI. BPV = Benign Positional Vertigo. Exertional= Exercise Induced Dizziness. PTMAD = Post Traumatic Migraine Associated Dizziness. Disorientation = Spatial Disorientation.

mented throughout treatment. The length of time required for patients to return to work after the initiation of physical therapy is monitored (Fig. 2).

## 3. Vestibular physical therapy treatment

The vestibular physical therapy rehabilitation strategy employs specific exercises designed to decrease dizziness, increase balance function, and increase general activity levels. Integration of the somatosensory, visual, and vestibular systems are coordinated for skilled spatial orientation. Exercises to decrease dizziness may focus on compensation or exposure to specific stimulus for habituation or attenuation of the response. Balance retraining involves exercises designed to improve organization of sensory information for balance control and coordination of muscle responses. General activity exercise involves a daily aerobic exercise program of progressive walking, cycling, or swimming. A vestibular physical therapy (VPT) program for mTBI patients consists of exercise procedures that target the vestibulo-ocular reflex (VOR), cervico-ocular reflex (COR), depth perception (DP), somatosensory retraining (SS), dynamic gait, and aerobic function. The VOR, COR, and DP exercises are graded in difficulty, based on velocity of head and object motion, and progression of body positioning from sitting to stand-

ing to walking. The SS exercises are graded in difficulty by narrowing the base of support, making the surface uneven, or changing the surface from firm to soft. Large amplitude head and trunk movements are also employed to increase somatosensory input. These exercises included the Proprioceptive Neuromuscular Facilitation (PNF) techniques of slow reversal head and neck patterns, modified chopping and lifting for head and trunk in progression from supine, to sitting, and standing postures and total body mass rolling activities. Varied walking exercises are graded in difficulty by changing direction, performing with the eyes closed, increasing speed of ambulation, walking on soft surfaces, or navigating stairs. An aerobic exercise home program progressively increases the time, speed, or distance that the patient can tolerate. All subjects are encouraged to work at their maximum tolerance while performing the VPT. Patients are instructed to perform the exercises twice daily at home. Patients are monitored by the physical therapist twice weekly for eight weeks. Patient compliance to the home exercise program is surveyed by the physical therapist during patient visits. The length of time required for patients to return to work after the initiation of physical therapy is monitored. Patients are instructed to perform the exercises twice daily at home. Patients are monitored by the physical therapist twice weekly for eight weeks. Patient compliance to the home exercise program is surveyed by the physical therapist during patient visits.

## 4. Multi-disciplinary team approach to goal setting

While the application of the exercises differs with our mTBI population as compared to other vestibular disorders, it is the multi-disciplinary team aspect in which mTBI care differs more significantly from other applications of vestibular rehabilitation. Many other disorders require a multi-disciplinary team, but the members of the team and the goals for an otherwise young and healthy individual differ remarkably from other such teams. Our center has instituted a program called the POWER: Program of Wellness Education and Recovery. The program utilizes team providers from physiatry, neuropsychology, primary care, vestibular physical therapy, occupational therapy, speech therapy, mental health, and case management. There are many program goals but ultimately the aim of the program is to focus on wellness and education with a positive expectation of recovery and return to duty through an organized and coordinate services and structured program. The vestibular balance awareness and safety course content includes an overview of vestibular anatomy and function, factors contributing to balance, strategies for decreasing dizziness and unsteadiness, how drugs affect motion sickness, and how alcohol affects vertigo. Alternative strategies such as mantrum repetition for relaxation, acupressure, rock wall climbing, and tai chi for fatigue reduction are included. A balance circuit training for return to duty links core strengthening with pilates, kettlebells, plyometrics, TRX, and agility drills with ball skills for coordination of learned balance strategies with common tasks.

## 5. Outcome measures for mTBI patients with vestibular pathology

There has been documentation on the reliability of CDP as a diagnostic tool and on the reliability of the DGI as a diagnostic tool [13,21]. But those studies have not looked at the head injury population which tends to have a different type of vestibular profile than those tested in previous studies. The head injury population is also a younger population than the previous studies represent. Similarly, there are several studies [1,2,19] examining the GST as an outcome measure and correlating this with postural stability over the last five years. In these studies the patient groups were small and again far different from our head injured blast patients both in terms of vestibular dysfunction and age. What might be considered normal for an older vestibular patient (post-stroke, etc.) would still be wholly unacceptable in this young military population intent on returning to active duty. Our study represents a demonstration of a suite of vestibular tests successfully utilized to judge outcomes in patients with both blunt and blast induced mTBI with vestibular disorders. Vestibular clinical centers will establish their own normal levels on patients of similar age and activity level. The standard results of these tests can be used to determine return to duty/work status as well as return to physical activity status. While the entire suite of tests provides valuable information, our data indicates that the vertical GST is the most sensitive outcome predictor for our population. This likely indicates that recovery of vestibular function is frequency and velocity dependent. This observation agrees with the work of Paige [17] in which linearity and symmetry of the VOR were examined.

## 6. Conclusion

Individuals with mTBI often demonstrate unsteadiness or disequilibrium [9,11]. There is a definitive impact of vestibular physical therapy intervention on dizziness and disequilibrium in mTBI patients whose headaches and vertigo are controlled by medical therapy. We and other authors have demonstrated that vestibular physical therapy is advantageous in improving functional dynamic visual acuity, standing balance and gait in mTBI patients with vestibulopathy. Customized exercise programs of gaze stabilization, dynamic visual acuity, static postural stability, dynamic postural stability, desensitization of head motion, aerobic conditioning yield the best results in symptom resolution. Rehabilitation options and length of treatment will differ depending upon the symptoms and associated polytrauma variables in these patients. Most mTBI patients respond to vestibular physical therapy intervention over 8 weeks. Some patients continue to improve with an additional 4 to 8 weeks of gaze stabilization and dynamic gait [4]. Using vestibular physical therapy in coordination with a structured multidisciplinary program dramatically improves symptom control and realization of functional self-goals. We advocate the employment of vestibular physical therapy for treatment of dizziness and disequilibrium in mTBI patients post blunt or blast head trauma.

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