12-10-2021

A Literature Review of Mild Traumatic Brain Injury Research

Brindlea Peterson
Western Michigan University, bpeterson1122@yahoo.com

Lee Honors College

WESTERN MICHIGAN UNIVERSITY

Western Michigan University
Lee Honors College

A Literature Review of Mild Traumatic Brain Injury Research: Seeing the Improvements and Acknowledging the Gaps in Current Literature

Brindlea Peterson

Thesis Chair: Ben Atchison, PhD, OTR/L, FAOTA, Professor Emeritus, Department of Occupational Therapy
Committee Member: Dr. Reddog Sina, DO, PhD, Department of Osteopathic Manipulative Medicine at Michigan State University College of Osteopathic Medicine

A thesis submitted for the partial fulfillment of requirements for the Lee Honors College for the completion of the degree of

Bachelor of Biomedical Science

Abstract

Mild traumatic brain injuries (mTBI) are a type of traumatic brain injury (TBI) usually sustained from an injury to the head and are hard to diagnose due to the lack of physical evidence seen in diagnostic radiology. The estimated worldwide rate of incidence each year is 42 million, making mTBIs rather common. In the US armed forces, that rate of incidence is even higher due to the dangerous nature of the work being done. Many complications can come from not properly addressing an mTBI after it happens which makes being able to determine an appropriate return-to-play or return-to-duty time very important for the long-term health of the injured people. Because of this, accurate diagnostic tools and clear prognostic rules are needed for medical professionals to be able to provide necessary care. This literature review thoroughly examines the existing literature on the current state of twenty-first century research regarding the incidence, prevalence, diagnosis and prognosis of mTBIs in both civilian and military populations. The review clearly outlines the areas that are still in need of improvement in order to best treat mTBIs moving forward.

Introduction

Mild traumatic brain injuries (mTBI) make up approximately 90% of all traumatic brain injuries (TBIs), making them among the most commonly diagnosed neurological disorders (Vos et al., 2012). Mild traumatic brain injuries are a type of traumatic brain injury (TBI) typically sustained from a sudden impact such as a forceful blow to the head referred to as a coup-contrecoup injury from an acceleration/deceleration trauma, commonly known as whiplash (Vos et al., 2012). Mild traumatic brain injuries have differing diagnostic factors from moderate, severe and critical traumatic brain injuries; though mTBIs may prove to be the most difficult to diagnose due to the fact that many symptoms that differentiate a mTBI from TBI do not show up immediately after the initial injury (Holm et al., 2005). A mTBI is, by definition, characterized by a hospital admission following a head injury, loss of consciousness less than 30 minutes if at all, and a Glasgow Coma Scale (GCS) of 13-15 (Vos et al., 2012). Conversely, the broad definition of a TBI, given by the *Journal of the American Medical Association*, is “an alteration in brain function or other evidence of brain pathology caused by an external force that can occur in traffic, at home, at work, during sports activities, and on the battlefield” (Manley & Maas, 2013). With an estimated worldwide annual incidence rate of 42 million people (Gardner & Yaffe, 2015), mTBIs are a prominent topic of research in the medical community.

The most common population groups that suffer mTBI’s are athletes, military personnel, and victims of domestic abuse (Gardner & Yaffe, 2015). A majority of research on mTBI prognosis has taken place in the civilian population. Some journal articles attribute this to the fact that data needs to be collected shortly after injury, a feat that is not always possible when a member of the military obtains this type of injury while on active duty (Boyle et al., 2014 & Belanger et al., 2016).

Mild traumatic brain injuries have a long history within the military community. During World War I, “shell shock” was the term used by soldiers and medical personnel to describe the concussive symptoms obtained from an injury to the head (Jones et al., 2007). During World War II, the focus around concussive symptoms shifted toward “post-concussion syndrome”, a condition marked by symptoms such as headaches, impaired memory, fatigue, dizziness, lack of concentration, and more (Jones et al., 2007).

Mild traumatic brain injuries gained attention when they were coined the “signature injury” of the 21st century conflicts in Iraq and Afghanistan (Combs et al., 2015). Studies after the conflicts ended reported that between 12-16% of all deployed veterans suffered a mTBI while on duty (Combs et al., 2015). According to the World Health Organization (WHO), annual incidence of mTBIs throughout the entire population is approximately 0.6% (Donovan et al., 2014). Though there are many more people in the civilian population, the ratio of injured veterans is much higher than those who have not served on active duty due to the dangerous nature of the conflicts.

Based on these numbers, it could be assumed that a higher amount of research on the veteran population would be conducted and used in advancing the literature on diagnosis and prognosis of mTBIs. During the 2004 World Health Organization International Collaboration on Mild Traumatic Brain Injury Prognosis, 313 studies were accepted as relevant for their review (Holm et al., 2005); of those 313 studies, only one was based on the military population (Boyle et al., 2014).

This thesis will examine the literature including the prevalence and incidence rates, definition, diagnosis, intervention and prognosis of mTBIs and how they affect both the civilian and military populations.

Civilian Population 2004 Meta-Analysis

Two major meta-analyses of the mTBI literature have been conducted on the diagnosis, prognosis and intervention for mild traumatic brain injuries. The first study published was by the 2004 World Health Organization Collaborating Centre for Neurotrauma Task Force on Mild Traumatic Brain Injury at the Karolinska Institute in Sweden. This study, which took place during the years 1998 to 2003 (Holm et al., 2005), focused on an evaluation of literature written between 1980 and 2000 (Donovan et al., 2014). This task force focused on 313 studies, 121 of which were primarily regarding epidemiology, 73 on diagnosis, 120 on prognosis, 16 on intervention, and 7 on economic cost. Of the 313 studies, 312 were based on the civilian population (Holm et al., 2005).

Incidence

In terms of incidence, the task force found that about .1-.3% of the worldwide population results in hospital-treated mTBIs and that between 70 and 90% of all treated traumatic brain injuries are considered mild (Holm et al., 2005). Self-reported brain injuries are more common, adding up to approximately .6% of the population annually, based on the task force's estimation (Holm et al., 2005). It was concluded that mTBIs are most prevalent among males, people ages 13-19, and young adults (Holm et al., 2005). Other findings relevant to incidence indicate that the validity of Second Impact Syndrome (SIS) during sports had not yet been established and that the studies based on incidence of SIS in sports were difficult to compare due to the differing circumstances of each study (Holm et al., 2005).

Diagnosis

The diagnostic procedures portion of the study found that of the hospital-treated mTBIs with a Glasgow Coma Scale of 13-15, only 5% (GCS score of 15) and 30% (GCS score of 13) have abnormalities on the intracranial computerized tomography (CT) scan (Holm et al., 2005), therefore showing that CT scan alone is not a conclusive method for diagnosing mTBIs. Of those patients with CT scan abnormalities, about 1% required neurosurgical intervention (Holm et al., 2005). Additionally, it was determined that the diagnostic accuracy of radiological examinations was poor for diagnosing skull fractures because of low sensitivity and that there was weak evidence of validity in cognitive testing or biochemical tests for mTBI (Holm et al., 2005).

Intervention

Very little information on the non-surgical intervention for treating mTBI was up-to-date (Holm et al., 2005). The studies that were accepted determined that providing patients with early educational information on mTBIs could help reduce long term complaints (Holm et al., 2005).

Prognosis

The prognostic studies were far more conclusive and confirmed that prognosis in children after a mTBI is good and that mTBI-related symptoms usually resolve within 2-3 months with very little evidence of residual deficits (Holm et al., 2005). Adult prognosis differs in that symptoms tend to persist longer (Holm et al., 2005). Cognitive deficits are common in the acute stage of the injury and other common symptoms (headache, dizziness, fatigue) typically resolve within 3-12 months (Holm et al., 2005). There is also evidence that where symptoms in adults persist, many had pending lawsuits in relation to their injuries (Holm et al., 2005). Most studies showed consistently that objectively measured mTBI-related deficits did not remain 1-3 months after the initial injury (Holm et al., 2005). However, self-reported symptoms lasted for a wide range of time (Holm et al., 2005). Athletes were found to have rapidly resolving symptoms after a sports-related concussion, though the task force speculated as to whether this was due to underreporting of symptoms in order to return to play more quickly (Holm et al., 2005). Other variables examined by the task force were that mTBI increased risk for seizures for the first 4 years post-injury, had no increased risk for brain tumor. There was no conclusion as to whether there was an increased risk for dementia, and that more severe mTBIs (GCS score of 13 or 14) had increased rates of disability (Holm et al., 2005).

Review

The 2004 conference resulted in a successful update to the literature, findings and guidelines of mTBIs. However, there were many noted gaps in the literature used in the comprehensive review. The Task Force clearly described the following areas as needing further research:

- watching documentation for evidence of deaths after repeated mTBI or concussions in order to further understand the validity of SIS;
- study the ability of clinical factors to predict the CT scan abnormalities and need for intervention in children;
- updated studies of cost analysis as most previous studies had been done over a decade prior to this analysis;
- studies comparing cost of direct versus indirect costs;
- well-designed, non-bias, confirmatory studies of symptom reporting and resolution over time using appropriate control groups;
- studies designed to support guidelines around emergency room triage of children with mTBI;
- studies around timing of interventions;
- a conclusive common definition and criteria of mTBI;

- an in-depth review of the existing criteria used to classify a traumatic brain injury as mild (Holm et al., 2005).

Civilian Population 2012 Meta-Analysis

The second review group, the International Collaboration on mTBI Prognosis (ICoMP), was funded and formed in 2011 to update the previous WHO Task Force and focused on 101 scientifically admissible studies from years 2001 to 2012 (Donovan et al., 2014). Unlike the previous study, this review was targeted specifically at the updates on the prognosis, both short and long term, of those with mTBI diagnosis (Donovan et al., 2014). Additionally, the 21 scientific researchers of the ICoMP made a point to use studies with more diverse populations, including different age groups spanning from young children to older adults, as well as athletes and military personnel (Donovan et al., 2014).

The review broke down their findings into a variety of categories, including sports concussions, mTBI in adults, mTBI after a motor vehicle collision (MVC), mTBI in pediatrics, and prognosis after mTBI following combat in a military conflict.

Return-to-Play Prognosis for Athletes

The first group reviewed was athletes in regards to sport concussions and return to play protocols following those injuries (Donovan et al., 2014). Some of the research paralleled the WHO Task Force findings in that most athletes tend to recover quickly both cognitively and in regards to post-concussion symptoms; though it was added that those with previous history of concussions presented with delayed recovery times over those with no previous concussion history (Donovan et al., 2014). As in 2004, the ICoMP also could not draw a conclusion regarding the prognosis for repetitive sports related concussions. However, given the information about recovery taking longer for athletes with previous concussion history, the ICoMP determined that this information should be used when making decisions regarding RTP in athletes who have sustained multiple head injuries (Donovan et al., 2014). Again, there were no sufficient studies pertaining to Second Impact Syndrome (SIS) after initial concussions (Donovan et al., 2014).

Prognosis in Adults

Much of the information around mTBI prognosis in adults is related to self-reporting of symptoms. The ICoMP found that self-reported symptoms were the most common reason for adults seeking care after a head injury as well as being the most common outcome after mTBI in adults (Donovan et al., 2014). The most recent evidence used by the ICoMP suggested that the typical self-reported symptoms (headache, fatigue, dizziness) were common and usually resolved within a few weeks to several months, which supports the findings of the WHO Task Force (Donovan et al., 2014 and Holm et al., 2005). Moreover, it was found that adult patients tend to minimize pre-existing symptoms when reporting mTBI or post-concussion symptoms and therefore may falsely attribute previous symptoms to the head injury. In addition, it was recognized that some of the self-reported symptoms were not specific to mTBIs but were found to appear equally in control groups, such as those with orthopedic injuries (Donovan et al., 2014). Because of this, the ICoMP recommended a change in the term from "post-concussion syndrome" in reference to the typical symptoms to the more general term of "post-traumatic symptoms" (Donovan et al., 2014). Another important finding in adults was that persistent symptoms and recovery duration is heavily associated with psychosocial factors, "such as poor expectations for recovery and negative injury perceptions" rather than being based solely on the injury related factors like the loss of consciousness (Donovan et al., 2014). Due to this, a high level of importance should be placed on the early recognition of the patient's psychosocial factors surrounding the injury (Donovan et al., 2014). One major change noted from the previous WHO Task Force to the ICoMP was full cognitive recovery in adults may take six months to a year rather than the first month post injury (Donovan et al., 2014).

Prognosis Following MVC

The ICoMP used multiple original studies including Cassidy et al. (2014) and Hartvigsen et al. (2014) to draw conclusions on the prognosis of patients who suffered mTBIs following MVC (Donovan et al., 2014). They found that approximately 24% of people who experience MVC injuries sustained a mTBI and that of those affected, 23% reported not having fully recovered after 1 year (Donovan et al., 2014). Furthermore, within the affected population, 90% reported neck pain, 84% reported headaches, 63% reported low-back pain and 58% reported mid-back pain. These symptoms were thought to contribute to poor recovery and longer recovery times in patients (Donovan et al., 2014). It was also noted that of these patients, 96% received ongoing care from medical physicians and approximately 62% also received treatments from other allied health professionals such as physical therapists and chiropractors (Donovan et al., 2014). The patients who reported seeking care from multiple health professionals were among those with the longest ongoing reported symptoms (Donovan et al., 2014). These studies combined suggest the important role that the other bodily injuries may play in the prognosis of a MVC related mTBI.

Prognosis for Pediatrics

Regarding pediatric prognosis after mTBI, recent evidence of the ICoMP was similar to the findings of the 2004 WHO Task Force in that for the majority of children, self-reported symptoms resolved rather quickly, usually within 2 to 3 months, and that there are no long lasting mTBI-specific cognitive deficits (Donovan et al., 2014). Additional evidence suggests that children with lower cognitive abilities and more complex mTBI reported more physical and cognitive deficits related to the mTBI at 3 months and 1 year post injury (Donovan et al., 2014). The ICoMP did not find any relative or acceptable studies pertaining to return to school protocols for children following mTBI (Donovan et al., 2014).

Military Personnel Prognosis

The *American Congress of Rehabilitation Medicine* published a separate review of the findings of the ICoMP specific to military personnel, of which it noted many important statistics and variables that differ greatly from the civilian population in regards to mTBIs (Boyle et al., 2014). To establish a basic level of understanding of all types of TBIs (mild, moderate, severe and critical) in military personnel, the review article provided some important details. First, the ratio of head and neck wounds in service members has doubled since the Vietnam War, whereas abdominal and thoracic injuries have greatly declined, likely due to the changing nature of war tactics as well as the improvements in armor and equipment used today (Boyle et al., 2014). Traumatic Brain Injuries (TBIs) were coined the signature injury in the Iraq and Afghanistan conflicts, along with Post Traumatic Stress Disorder (PTSD) (Boyle et al., 2014). One of the most common causes of TBIs in military personnel during these conflicts was exposure to large blasts from explosive materials (Boyle et al., 2014). Of those exposed to a blast, an estimated 60% to 80% sustain a TBI and approximately 75% of those are classified as mild (Boyle et al., 2014). Before diving into the prognosis, it is important to note a large difference in the studies between civilian and military personnel in that all military personnel noted in these studies would have received a comprehensive physical and psychological evaluation prior to being deployed, which may not be true of the civilian populations used in similar studies (Boyle et al., 2014). With that being said, it was found that prevalence of mTBI is indeed higher in military populations than in civilian populations, though there were still only 3 studies regarding military personnel that were deemed acceptable and used for this review (Boyle et al., 2014). Based on those studies, it was found that there was a high association between PTSD and postconcussive symptoms after a mTBI; however, it was specifically noted that the PTSD association was strictly with those who sustained only a mTBI and no other concurrent injury (Boyle et al., 2014). It was also found that PTSD likely had an impact on the prognosis of the injury, but due to the difference in timing of the studies because of the nature of the conflicts and the potential for more than one injury to occur in one deployment, it could not be concluded that there was a definite causal relationship between PTSD and mTBI affecting the prognosis of the mTBI (Boyle et al., 2014). Researchers have speculated that prognosis may be better for those who sustain a mTBI along with another injury because of the ability for a person to see the healing process of the other visible, physical injury (Boyle et al., 2014). This provides some level of reassurance and therefore lowers the likelihood that that same patient will develop PTSD (Boyle et al., 2014). The overall prognosis of mTBI alone in military personnel was similar to that of civilians in that there were initial findings of cognitive deficits that usually resolved themselves within 3 months of the injury, though there was not any data related to long-term outcomes or the prognosis of those with repeated head injuries from combat (Boyle et al., 2014).

Review

The ICoMP, like the WHO Task Force, found and noted many gaps in existing literature as of 2012 and noted areas for improvement. The following topics were found to be in need of further research:

- Return to Play (RTP) guidelines currently focus mainly on injury in males playing contact sports and would greatly benefit from further studies across a wider scope of genders, ages, and sports type;
- research quality of RTP remained the same between the 2004 review and the 2012 review and needs methodological improvements to better protect athletes from further injury;
- RTP analysis tools such as the Zurich Consensus guidelines are currently based on opinions and judgements from clinicians rather than scientific evidence, therefore the ICoMP recommends that randomized controlled trials be conducted to test the current RTP guidelines and make improvements based on the findings;
- improved research about SIS and any fatal outcomes after mTBIs;
- studies of methods for triage of those at higher risk for poor recovery early in the treatment, such as prognostic prediction rules, as well as whether early treatment programs are effective in improving recovery;
- a shift in research from biomedical markers to biopsychosocial markers for recovery after MBTI;
- studies regarding the relationship between mTBI and Whiplash Associated Disorder (WAD) and how their criteria should be separated from each other early during diagnosis to avoid overlap in prognostic research;
- return to school protocols for pediatrics after mTBI;
- longitudinal studies on the long and short term outcomes of military personnel to determine important characteristics of injuries in relation to prognosis;

- long term outcomes and effectiveness of the “return to duty” or “return to work after deployment” protocols;
- and the prognosis of military personnel who are exposed to multiple blasts while in combat (Boyle et al., 2014).

Military Personnel Meta-Analysis

Though only a small minority of the general reviews on mTBI literature have focused on the military population, there are, in fact, reviews of literature specific only to that population. One such study came during the later years of Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF), thoroughly examining the mTBI protocols that were used to screen any of the 1.8 million people who were deployed during those missions (Belanger et al., 2016).

The military initially began their post-deployment screenings for mTBI in April of 2007 (Belanger et al., 2016). The screening protocol was developed within the Department of Defense with limited field testing and sought to expose any veterans with previous mTBI and ongoing symptoms (Belanger et al., 2016). The screening itself consisted of a series of questions, including deployment location, previous TBI diagnosis, and then more detailed questions about injuries sustained and specific symptoms (Belanger et al., 2016). The goal of the Veterans Health Administration (VHA) was to not miss any undiagnosed brain injuries, noting that unlike the healthcare access within the civilian population, service members often return home months or years after the injury with little to no documentation of their injury outside of self-reports (Belanger et al., 2016). Whereas other injuries may be more obvious to see, it was easier for head injuries to be overlooked as the symptoms may not be visible to others and radiological diagnostic tools may not be able to see them either (Belanger et al., 2016). For the veterans that were screened and found to have positive symptoms or history of untreated mTBI, the veteran would then be referred to a TBI specialist where they would complete a Comprehensive TBI Evaluation (CTBIE) in order to confirm diagnosis and create a treatment plan (Belanger et al., 2016). This process received a lot of criticism from outside agencies, specifically the fact that all of the evaluations and treatments were based on subjective information that relied on the memory and recall of a patient with a possible brain injury; additionally, there was overlap of the symptoms being screened for in that many of the symptoms were associated with both mTBI and mental health conditions (Belanger et al., 2016).

The study found that between 2007 and 2014, 846,711 veterans of OEF and OIF were screened for any type of TBI (Belanger et al., 2016). Though the VHA concluded that the implementation of the screening process was successful, the study found that the screen may be missing between 30% and 64% of cases that were later diagnosed (Belanger et al., 2016). Additional research is needed to determine whether the mTBI screening process is effective and how it can be adjusted, as well as finding ways to objectively assess mTBIs, improve medical documentation in combat, and to ascertain whether or not screening for mTBIs post-deployment improves the actual clinical outcomes of those patients (Belanger et al., 2016).

King-Devick® (KD) Test

One additional screening tool that has been being researched in the military community for mTBI diagnosis is the King-Devick® (KD) test (Walsh et al., 2016). The Department of Defense reported 344,030 confirmed TBI cases between 2000 and 2015, 82.3% of which were mild (Walsh et al., 2016). The difficulty in knowing the reliability of that data is the lack of biomarkers or diagnostic tests to confirm mTBI (Walsh et al., 2016). The King-Devick® test is a tool that assesses eye-movement in a fast, easy to administer test (Walsh et al., 2016). Due to the cortical connection to visual processing, researchers are analyzing how mTBI affects visual processing and eye movement with hopes of developing objective diagnostic tools of ocular function, such as the KD test (Walsh et al., 2016). In this specific study, published in the *Journal of the Neurological Sciences*, the KD test was analyzed on 200 active duty members whereas previous studies had focused mainly on athletes (Walsh et al., 2016). The study showed significant differences in the KD test results between the mTBI group and the control group, with an average of about a ⅓ slower reading time for the mTBI group (Walsh et al., 2016). These findings showed that the KD test could be a valuable tool in combat in terms of determining return-to-duty abilities and being able to objectively see a change in cognitive function; however, there are also limitations and drawbacks to using the KD test (Walsh et al., 2016). One limitation is that there was no baseline testing done on the active duty members, a piece of information that would need to be collected to get more accurate results in the field (Walsh et al., 2016). Additionally, because the reading speed used to determine the results of the KD test is determined by the reader, the results of the test could yield false positive or negative results (Walsh et al., 2016). The study surmised that the KD test is a valuable screening tool to be used in combat; however, it should be used as an additional tool to other screening methods and that pre-injury KD data should be collected for all military members before entering combat for the best possible results (Walsh et al., 2016).

Recent Studies

Since the WHO Task Force in 2004 and the ICoMP in 2012 respectively, there have been many studies published focusing on advancing the research on mTBI diagnosis and prognosis, many of which address some of the previously listed areas of needed study.

Visual Biomarkers as Diagnostic Tools

Another group of researchers sought to further investigate the ability of using visual system biomarkers to diagnose mTBI, specifically in remote military settings (Ciuffreda et al., 2014). The researchers looked specifically at 3 types of oculomotor functions that are affected by mTBI: accommodation, version and vergence eye movements (Ciuffreda et al., 2014). Accomodation is the response of the eyes to focus on a nearby object, version is the average position of the two eyes, and vergence is the difference in the position of the two eyes (Ciuffreda et al., 2014). All three of these oculomotor functions have specific tests that can be done quickly to objectively determine the presence of a mTBI (Ciuffreda et al., 2014). The study showed that when the binasal occlusion (BNO) technique and the visual-evoked potential (VEP) amplitude was used to test for presence of mTBI, they were able to detect the presence of mTBI in >90% of the cases (Ciuffreda et al., 2014). BNO is the process of partially covering the visual field of the eyes so that the sector of the visual field that is next to the nose is covered for each eye (Ciuffreda et al., 2017). VEP is a test that measures the time it takes for the brain to respond to a visual stimulus (Ciuffreda et al., 2017). Based on these findings, it is very probable that vision biomarkers could be used as a helpful tool for diagnosing mTBI in settings in which quick return-to-duty decisions are needed to be made. Some limitations of this study included small sample sizes, so it was determined that more studies would be needed to further determine the validity of the tests for practical use (Ciuffreda et al., 2014).

Multimodal Diagnostic Tools

A study in 2016 by Baruch et al. looked to explore a multimodal approach to determining whether someone had previously obtained a mTBI. Rather than continuing to use one test to make a determination, researchers performed a study using a combination of eye-tracking, balance and stability, and neurocognitive assessments cumulatively to determine whether or not the subjects had previously suffered from a mTBI (Baruch et al., 2016). The subjects of the study were a group of athletes, civilians and military personnel who had suffered from a mTBI within the past 5 years as well as a control group (Baruch et al., 2016). The goal of this study was to create a platform that could use the multimodal approach to then give one combined score that would determine someone's likelihood of having a previous mTBI, all in hopes of finding an easy, portable system to be used in the field to help determine return-to-play and return-to-work protocols (Baruch et al., 2016). The study was successful in that the multimodal approach proved to be more effective than the singular test approach in determining previous mTBI; however, there were some limitations with the tests that the researchers determined would need to be changed for greatest efficacy such as the difficulty of the tests and the timing after the injury in which the tests are given (Baruch et al., 2016). Overall, the study was a step forward in finding a singular, portable system that can be used as a diagnostic tool in the field.

Persistent Post-Concussive Symptoms

Another study focused on the specifics of long term prognosis in regards to civilians with persistent (> 3 months) post-concussive symptoms (PCS) after mTBI (Oldenburg et al., 2016). The researchers in this study noted that many people continue to report such symptoms months to years after their mTBI; however, most meta-analysis studies on mTBI patients 3 months post-injury show small, non-significant portions of continuously affected people (Oldenburg et al., 2016). The most commonly reported persistent PCS was cognitive problems and upon further research, it was found that in past studies, patients with PCS performed worse in a comprehensive neuropsychological test than those with no PCS following mTBI (Oldenburg et al., 2016). This study went on to test the association between PCS and cognitive performance in mTBI patients with the goal of determining whether PCS would affect the performance in comparison to those who had recovered from their mTBI (Oldenburg et al., 2016). Following their study, it was found that mTBI patients showed reduced memory performance and concluded that mTBI may be linked to memory deficits (Oldenburg et al., 2016). This study will undoubtedly lead to further research in this subject area.

Assessing and Treating Mild Traumatic Brain Injuries in the Field: A Case Interview with Major RH, MS, OTL

Major RH was born and raised in Michigan surrounded by a supportive, highly-educated family. Growing up, she watched her cousin who had Cerebral Palsy undergo Physical Therapy as a constant treatment for her condition, inspiring her to pursue a career in Physical Therapy. Upon deciding to go to Western Michigan University for her undergrad, she chose the closest available program, Occupational Therapy. She completed her Bachelor's of Science degree at Western Michigan University as well as her master's in Occupational Therapy which she received in 2006. While at Western Michigan University, Major RH met people who motivated her to join the army. Though she had no prior knowledge or experience with the army, her mentors convinced her that she would be a great fit. She was commissioned into the army in 2006 as a First Lieutenant and went to Officer Basic Course for training before beginning the Occupational Therapy fieldwork program in January of 2007. She then completed a 9 month internship at Brooke Army Medical Center in San Antonio, Texas, during which she was trained and obtained experience in burn rehabilitation, amputee care, outpatient hand therapy, trauma, mental health, and traumatic brain injuries. After the internship, she transferred to Fort Leonard Wood in Missouri where she was stationed from 2008 until 2010 at which time she was moved to Fort Carson in Colorado. While at Fort Carson, she was deployed from February of 2011 until

February of 2012. In 2013 she was transferred one last time to Fort Sam Houston in San Antonio, Texas.

Major RH was picked to leave the medical unit that she was part of in Colorado to deploy to Afghanistan as an Individual Augmentee, or temporarily assigned asset, of the RC-South Division. While in Afghanistan, she was stationed at Forward Operating Base Lagman, located north of Kandahar in RC South in the Zabul province. She was primarily commanded by the 10th Mountain Division, a Light Infantry Division out of Fort Drum, New York. She was also sent out to the Brigade level in which she worked with 4 different groups, 2SCR, 82nd Airborne, 2nd Infantry, and the 25th Infantry. Additionally, she worked closely with a Navy Forward Surgical team who were also stationed on the base.

The main mission of the team, led by Major General Horoho, was to treat mTBI in theatre of operations in the field. Major General Horoho determined that Occupational Therapy was the strongest discipline to treat those mTBIs so a team of 10 occupational therapists and certified occupational therapy assistants were sent to establish mTBI recovery centers around the area. Major RH worked in conjunction with many units during this process, including route clearance, Explosive Ordnance Disposal (EOD), Navy Sea, Air and Land Teams (SEALs), and a Navy Forward Surgical team which was a fully functioning hospital equipped with surgeons, nurses, anesthesiologists, medics and Corpsman. Additionally, the units included essential support staff such as supply staff, food service, administrators, transportation, and others.

As part of these operations, Major RH's primary role was to assess, treat and monitor military personnel who had been diagnosed with an mTBI according to clinical guidelines. She also evaluated injuries to upper extremities and provided treatment support such as wound care or splinting. Her days consisted of a variety of events; some days she treated many patients or assisted in wound care after mass casualty events. Other days, when she did not have patients, the team would exercise, partake in education and training, attend in-services, assist in maintaining the treatment center, read, watch movies, or assist in the "sick-call" area (similar to urgent care). On the days that she or the team treated an mTBI patient, they would assess them daily and send reports to their division to track.

There were very specific guidelines that outlined who and when Major RH and her team would treat for mTBI. Anyone within 50 meters of a blast or anyone with direct head trauma would be brought to the Forward Surgical Team (FST), which is a small mobile surgical unit, to the aid station, or to the concussion recovery center and evaluated within 24 hours. After the evaluation, they would be required to rest out of duty for an additional 24 hours. If following the 24 hour rest period the symptoms had all resolved and they passed their testing, they could return to duty. If symptoms had not resolved or they did not pass the tests, they would be required to stay at the mTBI center to continue to be evaluated on a daily basis and perform exertional testing before being allowed to return to duty. Those who did not show signs of recovering would be sent to a higher level of care elsewhere.

There were multiple diagnostic tools used by Major RH and the other members of the team. One tool that they used included the Military Acute Concussion Exam (MACE), which is a quick medical screening used to gauge the severity of the head injury. Another tool used was neurological examinations such as cranial nerve screens, gait and coordination testing. The Balance Error Scoring System (BESS) and Romberg test were both also used to assess balance and any possible issues with the vestibular system. Exertion testing and Automated Neuropsychological Assessment Metrics (ANAM) were also used in more serious cases.

According to Major RH, the most significant challenge that she faced was not being able to clinically diagnose. The process of diagnosing required the occupational therapist to complete testing to determine that the person had a mTBI and then report to the physician assistant or doctor who in turn would have to record it in their documentation before the occupational therapist could begin treating the injured person. This was difficult because the concussion centers set up by Major RH and her team members were often short staffed, making it difficult to make those diagnoses. Another challenge in the process was getting injured service members to the concussion centers as the location was difficult to get to and required a helicopter to access. If there was a large group of injured personnel, they would often bypass the concussion centers to be taken to a larger medical facility in Kandahar instead. Due to this, there were many service members who may not have had the opportunity to be treated by the occupational therapy team.

The typical case that would be seen by Major RH would be an 18 year old male brought to the FST following a blast exposure while in 2nd truck back in a convoy, approximately 50 meters from the blast. The service member would present with a dazed feeling, headache, and ringing in his ears. The MACE would be administered and he would get a score of 24/30, which is considered abnormal. The mTBI would be diagnosed and then the service member would be put on 24 hour rest with no electronics, decreased lights, increased sugar intake and tylenol. The symptoms would continue on the second day so the veteran would be required to rest more. On the third day, the symptoms would be gone. The MACE would be readministered and the score would be 28/30, which is considered normal. Upon exertion testing, there would be no return of symptoms and he would be cleared to return to duty. If he had no further exposure for 1 year following the initial blast, he would be projected to have a good outcome. If he sustained multiple mTBIs within 1 year he would be considered at risk for long term symptoms.

This case study is a strong example of why accurate, easy-to-use diagnostic tools for mTBIs are greatly needed, especially in combat settings. Being able to clearly and quickly diagnose an mTBI would free up staff to reduce staffing shortages, possibly allow more clinicians the ability to diagnose and begin treating immediately, and ideally would be able to be done in any setting. Further research into this area would benefit not only military personnel, but also athletes and other civilians (H.R, personal communication, October 21, 2021).

Summary of Methods

The WHO Task Force, ICoMP, and VA all use varying methods for developing their research and literature reviews. The WHO Task Force chose their 313 articles (Holm et al., 2005) and the ICoMP chose their 101 articles (Donovan et al., 2014) based on scientific merit and included studies based on groups of people in mostly the civilian population as the civilian population has the highest incidence rate each year (Holm et al., 2005 & Donovan et al., 2014). The VHA literature review also used scientific merit to determine which studies were admissible for their review; however, they only reviewed research that had been published specifically about the military community (Belanger et al., 2016).

Conclusion

Based on the compilation of literature, it is clear that the importance of further studying mTBIs has been established and that improvements and discoveries have been made in diagnosing and treating mTBIs in the twenty-first century. For example, the ability to use visual feedback alongside other tests to more accurately diagnose an mTBI has given many people the knowledge to rest and recover after an injury. However, there is a significant amount of research yet to be done to be able to better understand, more accurately diagnose, and properly treat these injuries. One of the many areas in urgent need of further research is the effects of repeat mTBIs and the validity of SIS. It is imperative to the health of the world's military servicemen, athletes, and general population that the research and advancements for diagnosis and treatment of mTBIs continue.

References

Baruch, M., Barth, J. T., Cifu, D., & Leibman, M. (2016). Utility of a multimodal neurophysiological assessment tool in distinguishing between individuals with and without a history of mild traumatic brain injury. *Journal of Rehabilitation Research & Development, 53*(6), 959–971. https://doi-org.libproxy.library.wmich.edu/10.1682/JRRD.2015.06.0120

Belanger, H. G., Vanderploeg, R. D., & Sayer, N. (2016). Screening for Remote History of Mild Traumatic Brain Injury in VHA: A Critical Literature Review. *The Journal of Head Trauma Rehabilitation, 31*(3), 204–214. https://doi.org/10.1097/HTR.0000000000000168

Boyle, E., Cancelliere, C., Hartvigsen, J., Carroll, L. J., Holm, L. W., & Cassidy, J. D. (2014). Systematic Review of Prognosis After Mild Traumatic Brain Injury in the Military: Results of the International Collaboration on Mild Traumatic Brain Injury Prognosis. *Archives of Physical Medicine and Rehabilitation, 95*(3), S230–S237. https://doi.org/10.1016/j.apmr.2013.08.297

Ciuffreda, K., Ludlam, D. P., Thiagarajan, P., Yadav, N. K., & Capo-Aponte, J. (2014). Proposed objective visual system biomarkers for mild traumatic brain injury. *Military Medicine, 179*(11), 1212–1217. https://doi.org/10.7205/MILMED-D-14-00059

Ciuffreda, K. J., Yadav, N. K., & Ludlam, D. P. (2017). Binasal Occlusion (BNO), Visual Motion Sensitivity (VMS), and the Visually-Evoked Potential (VEP) in mild Traumatic Brain

Injury and Traumatic Brain Injury (mTBI/TBI). *Brain Sciences, 7*(8), 98. https://doi.org/10.3390/brainsci7080098

Combs, H. L., Berry, D. T. R., Pape, T., Babcock-Parziale, J., Smith, B., Schleenbaker, R., Shandera-Ochsner, A., Harp, J. P., & High, W. M. (2015). The Effects of Mild Traumatic Brain Injury, Post-Traumatic Stress Disorder, and Combined Mild Traumatic Brain Injury/Post-Traumatic Stress Disorder on Returning Veterans. *Journal of Neurotrauma, 32*(13), 956–966. https://doi.org/10.1089/neu.2014.3585

Donovan, J., Cancelliere, C., & Cassidy, J. D. (2014). Summary of the findings of the International Collaboration on Mild Traumatic Brain Injury Prognosis. *Chiropractic & Manual Therapies, 22*(1), 38–38. https://doi.org/10.1186/s12998-014-0038-3

Gardner, R., & Yaffe, K. (2015). Epidemiology of mild traumatic brain injury and neurodegenerative disease. *Molecular and cellular neurosciences*, *66*(Pt B), 75–80. https://doi.org/10.1016/j.mcn.2015.03.001

Holm, L., Cassidy, J. D., Carroll, L., & Borg, J. (2005). Summary of the WHO collaborating centre for neurotrauma task force on mild traumatic brain injury. *Journal of Rehabilitation Medicine, 37*(3), 137–141. https://doi.org/10.1080/16501970510027321

Jones, E., Fear, N. T., & Wessely, S. (2007). Shell Shock and Mild Traumatic Brain Injury: A Historical Review. *The American Journal of Psychiatry, 164*(11), 1641–1645.

https://doi.org/10.1176/appi.ajp.2007.07071180

Manley, G. T., & Maas, A. I. R. (2013). Traumatic Brain Injury: An International Knowledge-Based Approach. *JAMA : the Journal of the American Medical Association, 310*(5), 473–474. https://doi.org/10.1001/jama.2013.169158

Oldenburg, C., Lundin, A., Edman, G., Nygren-de Boussard, C., & Bartfai, A. (2016). Cognitive reserve and persistent post-concussion symptoms-A prospective mild traumatic brain injury (mTBI) cohort study. *Brain Injury, 30*(2), 146–155. https://doi.org/10.3109/02699052.2015.1089598

Walsh, D. V., Capó-Aponte, J. E., Beltran, T., Cole, W. R., Ballard, A., & Dumayas, J. Y. (2016). Assessment of the King-Devick® (KD) test for screening acute mTBI/concussion in warfighters. *Journal of the Neurological Sciences*, *370*, 305-309.

Vos, P. E., Alekseenko, Y., Battistin, L., Ehler, E., Gerstenbrand, F., Muresanu, D. F., Potapov, A., Stepan, C. A., Traubner, P., Vecsei, L., & Von Wild, K. (2012). Mild traumatic brain injury. *European Journal of Neurology, 19*(2), 191–198. https://doi.org/10.1111/j.1468-1331.2011.03581.x