Return to Combat Duty after Concussive Blast Injury†

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Abstract

Little data exist regarding the acute assessment of blast concussion and the course of recovery in the combat zone, as most research has examined service members long after they have returned home. This manuscript examined a case series of 377 service members seen for acute concussion evaluation following medical evacuation from the battlefield in Helmand Province, Afghanistan. Of these, 111 were assessed for concussion prior to their return to the continental USA for other severe physical injuries. Of the remainder, and when comparing those who returned to duty (RTD)/recovered from concussion in the combat zone and those who did not, data indicate that those who did not RTD were older and were more likely to endorse symptoms of combat stress. Quicker recovery times were associated with less severe headaches and fewer acute symptoms at the time of injury as well as the absence of combat stress reaction. Variables that were not associated with RTD and/or recovery were Military Acute Concussion Evaluation (MACE) cognitive scores and whether or not individuals suffered loss of consciousness. While MACE scores were not associated with recovery, they were deemed clinically useful as a part of a serial concussion evaluation if the initial MACE was given within 6 h of the blast. Implications for battlefield concussion assessment and management as well as future research directions are discussed.

Keywords: Assessment; Head injury; Traumatic Brain Injury; Posttraumatic stress; Disorder

Introduction

In today’s war on terrorism, it is well known that the enemy’s primary weapons are various types of blasts, which not only cause physical injuries, but due to their randomness, are geared to create psychological ones as well (Goldberg, 2010; Terrio et al., 2009). Improvised explosive devices (IEDs) and rocket and mortar attacks have been the hallmark weapons of the war. Often labeled a signature wound of the current conflicts, concussion (also referred to as mild Traumatic Brain Injury) is the most common injury, with estimates of 15.2% prevalence (Hoge et al., 2008), accounting for 78% of all injuries to service members (Owens et al., 2008).

Despite the significance of blast concussive injuries since World War I (Kennedy, Boake, & Moore, 2010), there is little empirical literature on the topic. Additionally, the majority of current research on blast concussion is conducted after service members return home from the combat theater (Brenner et al., 2010; Belanger, Kretzmer, Yoash-Gantz, Pickett, & Tupler, 2009; Lippa, Pastorek, Benge, & Thornton, 2010; Schneiderman, Braver, & Kang, 2008; Schwab et al., 2007; Trudeau et al., 1998; Warden, 2006). This offers little empirically based guidance and practical application for clinicians in

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theater, and it provides inadequate information about the sequelae, recovery times and returned to duty (RTD) rates of concussive blast injuries. Given the prevalence of blast concussion, it is essential that medical personnel on the front lines are able to accurately assess blast concussions and make informed RTD decisions. This must be done in a dangerous environment that simultaneously accommodates the health and wellbeing of service members while keeping in mind the requirements of the operational mission.

Given the paucity of the empirically based guidance on concussive blast injuries, the U.S. military adopted a sports concussion paradigm for assessment and RTD decisions (Barth, Freeman, Broshek, & Varney, 2001; Erlanger et al., 2003; Maddocks, Dicker, & Saling, 1995; McCrea et al., 1998). Although this paradigm has provided useful information for military medical providers and was an excellent starting point for relevant concussion definition and assessment, the mechanisms of injury from a blast and the risk for severe co-occurring psychological effects vary significantly from what is typical in a sports setting. There are four potential mechanisms of blast injury: primary (blast wave alone), secondary (hit by flying object), tertiary (thrown), and quaternary (other explosion-related injuries such as toxic exposure; Burgess et al., 2010; DVBIC, 2009). With the exception of quaternary mechanisms, a service member can be concussed by one or a combination of these mechanisms. (For more information on the primary, secondary and tertiary effects of blast, see Bauman et al., 2009; Cernak et al., 1996; Cernak, Wang, Jiang, Bian, & Savic, 2001; French, Spector, Stiers, & Kane, 2010; Howe, 2009; Kaur et al., 1995; Long et al., 2009; Mundie, Dodd, Lagutchik, Morris, & Martin, 2000; Säljö, Arrhen, Bolouri, Mayorga, & Hamberger, 2008; Taber, Earden, & Hurley, 2006.)

Despite an improved understanding of blast mechanics, the scientific literature is still limited on the question of how the deficits and symptom presentation of blast injuries differ from concussions of other etiologies (Nelson et al., 2010). Luethcke, Bryan, Morrow, and Isler (2011) found that there were some differences between blast and non-blast concussion groups acutely, with non-blast concussions more frequently experiencing loss of consciousness (LOC), headache, balance problems, nausea and vomiting and blast concussion more frequently associated with hearing problems (see also Belanger et al., 2011). Belanger and colleagues (2009) attempted to distinguish performance on the standard neuropsychological measures between service members with a blast-related concussion from those with a non-blast-related concussion and found no statistically significant performance differences between the two groups. However, consistent with many other studies examining blast concussion, the neuropsychological evaluations in this study occurred an average of 1024 days after the injury.

While there are many questions yet to be answered, there is a widespread acceptance that blast concussive injuries represent serious injuries and in order to eliminate the stigma attached with seeking medical services in the combat zone, the military created mandatory screening criteria following potential concussive injuries. Concussion screenings are mandated for all service members who have been in a vehicle involved in a blast, vehicle accident, or rollover, who were within 50 m of a blast, or who sustained a blow to the head (Department of Defense [DoD], Department of Defense, 2010). As greater numbers of service members are referred for blast injury assessment, clinicians face challenges of accurate and efficient assessment, appropriate management and treatment, and determining when to return a service member to combat operations while balancing both operational requirements and service member health.

With regard to evaluation, the Military Acute Concussion Evaluation (MACE) is the concussion assessment tool deployed by the DoD for in the theater evaluation of acute concussion (DVBIC, 2007). Clinical practice guidelines informing RTD decisions after a concussion were developed by DVBIC (Barth, Isler, Helmick, Wingler, & Jaffee, 2010) and rely heavily on the MACE. The MACE is a screening tool developed in 2006 to provide medical personnel closest to the point of injury with a quick means of assessing injured service members’ cognitive performance and subjective report of symptoms (Barth et al., 2010; Coldren, Kelly, Parish, Dretsch, & Russell, 2010; DVBIC, 2007). The MACE is intended to be administered by a field medical provider (corpsman/medic) and is divided into three sections: a subjective report of the event and current symptoms, a brief measure of orientation, immediate memory, concentration and delayed recall, based on the Standardized Assessment of Concussion (SAC; McCrea et al., 1998) and a gross neurological screening. While there is literature on the SAC in the sports concussion population, there was none on the MACE at the time of implementation in theater. Recent research indicates that if the MACE cognitive score is administered more than 12 h after the blast injury, it lacks the psychometric properties to be deemed clinically useful (Coldren et al., 2010); however, to date, this is the only guideline offered by an empirical study on use of the MACE with acute blast concussion in the combat theater. It should be noted that the MACE and the concussion clinical practice guidelines were recently revised. While the instrument has not changed, with the exception of the addition of three more forms, implementation and clinical guidelines have been updated and improved upon (DVBIC, 2012).

There are significant risks of returning service members to the battlefield before they have fully recovered from a concussive injury. There has been an increasing focus in the sports medicine literature on the dangers of athletes returning to play (RTP) before they have recovered. The most common concern associated with premature RTP is the increased risk of second injury,
which may, in turn, prolong recovery and further delay subsequent RTP. Other risks are the rare second-impact syndrome (Cantu & Gean, 2010) and chronic traumatic encephalopathy (Mckee et al., 2009).

In addition to concerns regarding service members’ physical health, the ability to perform a combat role effectively is of serious concern to clinicians and military leaders. In order to be effective in combat, service members must be able to complete an accurate assessment of their environment, rapidly process information, and quickly make critical decisions (Bates et al., 2010). Due to “the complexity, speed, and lethality of modern warfare, even small mental lapses may have catastrophic consequences” (Friedl et al., 2007). The sports concussion literature indicates that symptomatic athletes show performance deficits in verbal memory, visual memory, and processing speed, all of which are critical in combat roles (Belanger & Vanderploeg, 2005; Lew, Thomander, Chew, & Bleibert, 2007). Therefore, in addition to concerns regarding the service member’s health, returning a service member to duty too soon may result in poor performance, which on the battlefield can be the difference between life and death, as well as success or failure of the mission.

There are complicating, individual factors that clinicians must consider when an individual fails to recover from a concussion within a typical time-frame that include stress disorders, personality disorders, substance abuse, other medical problems, prior concussive history, and situational factors (Carroll et al., 2004; Howe, 2009). There are indications that athletes with previous concussions are likely to experience a delayed recovery compared with their peers without a prior concussion history (Collins et al., 1999). Additionally, psychological problems represent a significant barrier to recovery as a large number of combat troops are returning from deployment with depression, anxiety, and/or post-traumatic stress disorder (PTSD), which has been estimated to be as high as 44% (Lapierre, Schwelger, & Labauve, 2007). Polusny and colleagues (2009) found elevated levels of PTSD and depression in troops who had already served a prior combat deployment, when they were assessed 1 month before returning to a combat theater.

Consistent with the adaptation of many of the sports concussion guidelines, the military has generally adapted the guidelines that suggest most athletes RTP within a week. Although there are a number of studies on RTP after a sports concussion (McCrory et al., 2009), there are no empirical studies with a large sample size that address the average length of recovery time from a blast injury. Further, on the battlefield, resources are critical for mission success. However, military leaders must balance the long-term health of their troops with the operational mission. In order to achieve this delicate balance, military leaders and clinicians must have empirically based guidelines on how long service men and women must be held out of the fight to ensure their immediate and long-term health and combat effectiveness.

Although the sports concussion literature has provided a large knowledge base on multiple aspects of concussion injuries, current research indicates that blast-induced concussive injuries represent a more complex injury than sports concussion. This exploratory study was conducted in order to describe a representative group of blast concussed service members at the time of injury and follow them through the recovery period in order to better inform policy, provide best practices as concussion recovery centers are implemented in the combat zone, better train providers in identifying and managing concussion, and to evaluate those factors which might contribute to poor or successful recovery outcomes. Finally, we wanted to further examine the utility of the MACE, the primary means of concussion assessment used in the combat zone.

Methods

Project approval was obtained from the Joint Combat Casualty Research Team and it was designated a Performance Improvement Project.

Participants

Participants included 377 consecutive U.S. service members medically evacuated to the Camp Bastion Role III combat hospital in Helmand Province, Afghanistan, between May and 1 November 2010, who met the mandatory screening criteria for concussion (i.e., within 50 m of a blast, in a vehicle accident/rollover or struck in the head; DoD, 2010). Of the sample, 374 were men, 327 were Marines, 38 were Army, 11 were Navy and 1 was Air Force. Rank of the sample generally reflected the composition of the military with the most frequently concussed rank that of E-3 (i.e., Marine Corps Lance Corporal). Of the 377 service members, 9% did not meet criteria for a concussion, 52% met criteria for a concussion which included LOC and 39% met criteria for a concussion without LOC. Of the sample, 113 had never experienced a prior concussion of any kind, whereas the remainder of the sample reported one or more (one prior concussion = 89; 2 = 55; 3 = 30, 4 = 21; 5 = 17; 6 = 9; 7–10 = 11; 11–15 = 5). Approximately 53% of the sample had not experienced a prior blast concussion. Of those that did, 68 had experienced one, 32 had two, 14 had three, 1 had four, 4 had five, and 2 had a history of six prior blast concussions. Although prior military concussions were impossible to verify, usually prior combat zone blast concussive diagnoses were able to be confirmed via the in theater concussion database and/or the Theater Medical Data Store (an internet-based
electronic medical record used in the combat zone in both Iraq and Afghanistan). The vast majority of current concussions were deemed due to a primary blast from an IED without impact to the head \((n = 212)\), as determined by individual report, collateral report, and physical examination of the head. Other concussive injuries were due to blast concussion from rockets/mortars (25), hand grenade blast (6), and rocket backblast (3). The remainder of the sample experienced an IED blast with secondary impact to the head (67), an IED blast in which the individual was thrown (21), vehicle rollover (8), and non-blast concussions (22).

Concussion Evaluation

The concussion evaluation initially consisted of an on scene evaluation performed by a corpsman or medic when conditions allowed (i.e., absence of more concerning physical injuries, safe area for the assessment, etc.) and which generally consisted of the MACE.

Military Acute Concussion Evaluation

The first section of the MACE obtains an account of the concussive event and a subjective report of current symptoms. These symptoms include LOC, anterograde and retrograde amnesia, headaches, dizziness, memory problems, balance problems, nausea/vomiting, difficulty concentrating, irritability, visual disturbances, and tinnitus. Corpsmen and medics are trained to make medical evacuation decisions based on red flags, symptoms indicating a potential serious neurological problem (e.g., worsening headache, seizure, and repeated vomiting) and on safety to the individual/mission based on symptom presentation (e.g., unable to walk on own accord, significant confusion, and visual disturbances). The second (cognitive) section of the MACE, based on the aforementioned SAC, provides a brief objective measure of orientation, immediate memory, concentration, and delayed recall. The third part of the MACE is a gross neurological screening, with visual, speech, and motor components. Based on the service member’s performance, he/she receives a score from 0 (severely impaired) to 30 (no impairment) for the cognitive score (McCrea et al., 1998); a Red or Green classification for a positive or negative neurological screening; and an A or B for positive symptom report or negative symptom report, respectively (e.g., a score expressed as 25/R/B indicates a 25 of 30 achieved on the cognitive portion, at least one finding on the neurologic screen and the presence of at least one symptom).

Service members were then medically evacuated via air (the most typical route in Afghanistan) or ground to the combat hospital for concussion symptoms and/or other physical injuries. Upon arrival to the hospital, service members were evaluated by an American or British emergency room physician and received a head CT when indicated. If service members were immediately taken into surgery for other injuries, the concussion evaluation occurred post-surgery once the service member was able to participate in the evaluation (this differed due to the varying degrees of injury). At times, the concussion evaluation occurred prior to surgery if the service member was stable and alert while awaiting his/her turn in the operating theater.

Following the initial ER evaluation, each service member was assessed by a psychiatric technician and a neuropsychologist for concussion, using the American Academy of Neurology (AAN) grading criteria (AAN, 1997). The MACE was administered if it had not already been given on the battlefield, resulting in significant variability in the amount of time between the concussive event and the MACE administration. It is important to note that the MACE was not used as a diagnostic instrument within the combat hospital given the level of medical care available (i.e., the MACE is intended for battlefield use by enlisted corpsmen/medics); rather it was given in order to get a gross estimate of the current level of cognitive function and to provide a point of comparison. A concussion history was taken which included all prior concussions or other brain injuries. Headache severity (pain scale of 0–10 with 10 being worst) was assessed. Time of injury and educational level were recorded as a part of the evaluation, as was the time of the MACE administration. A set of 13 symptoms (Table 5) were assessed in addition to LOC and stress symptoms. The internal consistency (reliability) of the resulting 13-item Symptom Scale for this sample was 0.76 (Cronbach’s \(\alpha\): \(n = 350\)).

Combat Stress

A series of clinical interviews were completed by the neuropsychologist to assess for the presence of acute combat stress symptoms (e.g., symptoms of acute stress disorder, somatization, and conversion). These began in the ER. Observation of service members within the ER and the hospital was also conducted as it pertained to their reactions to the constant opening and closing of doors, other loud noises (e.g., controlled explosions), reactions to other wounded service members, interaction with the local male family members on the ward chaperoning wounded children, presence of detainee-patients, and so on. The manifestation of hyperstartle, hypervigilance, and irritability, for example, were usually detected through
observation as opposed to interview alone. Other combat stress-related problems (e.g., guilt and shame) were garnered during the clinical interviews and observation of interactions with members of their command. Physical symptoms felt to be manifestations of combat stress (e.g., complete temporary blindness and/or deafness) were also monitored until resolution. Please note that any symptom of a combat stress reaction was deemed combat stress. Service members rarely met criteria for a mental health diagnosis.

Return to Duty Procedures and Criteria

Service members who were not returned to the continental USA (CONUS) due to other physical injuries (e.g., fractures, severe shrapnel wounds, amputations, etc.), but who were diagnosed with concussion faced three potential dispositions: hospitalization in the combat hospital, partial hospitalization in the Contingency Aeromedical Staging Facility (usually for individuals who were being aeromedically evacuated from the combat theater—this facility afforded 24-h nursing staff, Navy and Air Force flight surgeons, and multiple Air Force medics and was provided as a concussion step-down unit until one was built on the adjacent Camp Leatherneck in 2011) or discharge to the Wounded Warrior Battalion (or their command if they were housed on Camp Leatherneck) for outpatient care at the Concussion Restoration Care Center (CRCC), located on Camp Leatherneck (a U.S. Forward Operating Base adjacent to the British-run Camp Bastion).

Hospitalization and partial hospitalization standards were quite liberal in the combat zone for a primary diagnosis of concussion given such environmental hazards as the lack of even walking surfaces and the need to walk significant distances in extreme heat to get meals, shower, and so on. However, once service members were deemed safe to walk independently and other significant symptoms resolved, they were treated and monitored at the CRCC. The CRCC staff consisted of a sports medicine physician, a primary care physician, a psychologist, an occupational therapist, a physical therapist, a nurse, and five corpsmen. Service members were provided pain and sleep management, vestibular rehabilitation, physical therapy (for rehabilitation of shrapnel injuries, etc.), acupuncture, combat stress care, audiograms (in conjunction with the British hospital), cognitive screening (Automated Neuropsychological Assessment Metric; ANAM), education on topics such as concussion, sleep, and combat stress, and in the case of individuals who were not returning to predeployment levels on the ANAM, neuropsychological evaluation. In order to RTD, service members had to have full symptom resolution as determined by denial of all symptoms, ANAM testing consistent with pre-deployment testing (or cleared through traditional neuropsychological evaluation) and no return of symptoms when provided formal exertional testing (i.e., physical activity to raise heart rate and intracranial pressure).

Results

Forty-six percent of the sample (n = 156) did not RTD in the combat zone. Breaking this down, 111 service members did not RTD primarily as a result of other physical injuries (it should be noted that all of these individuals were aeromedically evacuated CONUS and were not followed in the combat zone beyond the initial evaluation) and 45 service members did not RTD primarily as a result of blast concussion. It is notable that 16 of these 45 experienced three blast concussions on their current deployment and were held out of combat for the remainder of the deployment regardless of symptom resolution per DoD policy (i.e., the “three strikes and you are out” rule; see DoD, 2010). Consequently, these 16 subjects were excluded from the analyses.

When comparing the RTD group (n = 187) to the group of service members who did not RTD solely due to concussion (n = 29), the groups were similar in education, symptom scale scores, MACE cognitive score, and headache rating. The group that did not RTD was slightly older—t(207) = 2.15; p = .032; 26.8 versus 24.5—and was more than three times as likely to have stress symptoms than the RTD group (25% vs. 8%; odds ratio = 3.86, 95% CI, 1.40–10.64). See Table 1 for a comparison of the non-RTD/aeromedical evacuation group, non-RTD concussion group, and the RTD group.

When examining the question of how long it takes to recover from a blast concussion, the RTD group fell into two groups. Approximately one-half of the RTD group (n = 92) returned to duty (i.e., recovered) following an average of 7.6 days following their injury (prompt group; range = 0–13 days), while the other half (n = 88) of returned to duty following an average of 24.4 days (delayed group; range = 14–51 days). See Table 2 for a comparison of the prompt and delayed RTD groups.

As shown in Table 2, significant group differences were observed between prompt and delayed RTD on only two continuous variables, Symptom Scale total score and reported headache severity rating and one dichotomous variable, combat stress. These were the only variables where the effect size of the group differences was in the moderate range (Cohen, 1988).

Due to the exploratory nature of this study, stepwise linear regression (continuous outcome) and stepwise logistic regression with backward deletion based on likelihood ratios (categorical outcome) were utilized to further evaluate these predictors. Four variables were significant in the prediction of the likely number of days until RTD/recovery (Table 3). The linear combination of Symptom Scale total score, other physical injuries, number of prior blast concussions, and the presence of stress symptoms
accounted for approximately 21% of RTD variance and were of nearly equivalent importance as revealed by their regression weights (0.184–0.277). Although statistically significant, it should be noted that the standard errors of the estimated recovery time was 9.3 days. Similar results, in terms of variables included, level of statistical significance, and percent of accounted for variance, were obtained following logistic regression to predict the categorical outcome (Table 3). The unique aspect of the logistic regression findings reflects the impact of each variable after statistically controlling for the other variables in the equation. In other words, each of the four variables had higher odds ratios \([\text{Exp}(B)]\) and lower \(p\)-values when they were independently evaluated. It should also be noted that, in contradiction to current operational practice, the service member’s MACE cognitive score was not included in either of these stepwise regression equations.

In view of the novel contribution of the Symptom Scale, another pair of stepwise regression equations was calculated using the 13 symptoms as potential predictors of either estimated RTD days or the RTD group (Table 4). Once again a subset of four variables was identified through each approach as the most parsimonious prediction of the selected outcome. The linear combination of Confusion, Visual Disturbance, Irritability, and Memory Problems accounted for 22% of RTD variance, with a standard error of the estimate of 9.6 days. As in the previous linear equation, the relative impact of each of these four variables was nearly equivalent (\(b\): 0.180–0.260). Unlike the previous pair of regression equations, the stepwise logistic predictor set was not identical to the stepwise linear predictor set. Specifically, in the logistic regression Tinnitus replaced Visual Disturbance as a significant predictor (odds ratio \(= 3.55, p = .002\)). This equation accounted for approximately 26% of outcome variance and exhibited 64.7% classification accuracy. The 13 symptoms varied considerably in incidence (Table 5) from a nearly omnipresent Confusion (odds ratio for delayed RTD \(= 7.74\)) to a fairly rare Irritability (odds ratio for delayed RTD \(= 6.53\)). Two additional dichotomous variables are also reported in Table 5 in order to facilitate their comparison with the Symptom Scale variable. Despite an incidence of 50%, LOC was not a significant predictor of delayed RTD (odds ratio = 1.31; 95% CI, 0.73–2.36). On the other hand, combat stress was a significant predictor of group membership (odds ratio = 4.15; 95% CI, 1.12–15.43).

Finally, given that the MACE cognitive score was neither diagnostic nor predictive, we looked at the time between the concussive injury and MACE administration (within 6 h, \(N = 131\), mean MACE = 22.92, \(SD = 4.6\); 6–12 h, \(N = 45\), mean MACE = 25.36, \(SD = 3.4\); >12 h, \(N = 78\), mean MACE = 24.15, \(SD = 4.7\)). Scores for the within 6-h group were significantly lower than the 6–12-h group \((p = .006)\). There was no significant difference between the 6–12-h group and the >12-h group. MACE did not predict RTD times with 49% of MACE cognitive score failures (i.e., <25) returning promptly while 51% were delayed in their RTD.

### Table 1. Comparisons of those who were aeromedically evacuated quickly for other physical injuries (swift evac), those who did not RTD due to diagnosis of concussion and those who recovered/RTD

<table>
<thead>
<tr>
<th>Variable</th>
<th>Non-RTD swift evac (mean [SD])</th>
<th>Non-RTD concussion (mean [SD])</th>
<th>RTD (mean [SD])</th>
<th>(F)</th>
<th>(df)</th>
<th>(p)-value</th>
<th>Partial (\eta^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>23.9 (4.3)</td>
<td>26.8 (5.7)</td>
<td>24.5 (5.3)</td>
<td>3.87</td>
<td>2,314</td>
<td>.022</td>
<td>0.018</td>
</tr>
<tr>
<td># prior non-blast concussions</td>
<td>1.2 (1.9)</td>
<td>1.3 (1.3)</td>
<td>1.3 (2.0)</td>
<td>0.16</td>
<td>2,294</td>
<td>.855</td>
<td>0.008</td>
</tr>
<tr>
<td># prior blast concussions</td>
<td>0.4 (0.9)</td>
<td>0.8 (1.3)</td>
<td>0.5 (0.9)</td>
<td>2.04</td>
<td>2,300</td>
<td>.132</td>
<td>0.005</td>
</tr>
<tr>
<td>Total # prior concussions</td>
<td>1.6 (2.4)</td>
<td>2.1 (2.0)</td>
<td>1.8 (2.3)</td>
<td>0.63</td>
<td>2,294</td>
<td>.536</td>
<td>0.008</td>
</tr>
<tr>
<td>MACE Cognitive Score</td>
<td>24 (5)</td>
<td>23 (5)</td>
<td>23 (5)</td>
<td>0.56</td>
<td>2,230</td>
<td>.737 &lt;.001</td>
<td></td>
</tr>
<tr>
<td>Headache Severity</td>
<td>5.2 (3.8)</td>
<td>6.7 (2.9)</td>
<td>5.8 (2.9)</td>
<td>2.76</td>
<td>2,296</td>
<td>.065</td>
<td>0.013</td>
</tr>
<tr>
<td>Symptom Scale</td>
<td>4.5 (3.3)</td>
<td>6.1 (2.2)</td>
<td>5.2 (2.5)</td>
<td>4.50</td>
<td>2,294</td>
<td>.012</td>
<td>0.009</td>
</tr>
<tr>
<td>Education (years)</td>
<td>12.7 (1.3)</td>
<td>12.8 (1.4)</td>
<td>12.7 (1.3)</td>
<td>0.12</td>
<td>2,292</td>
<td>.883</td>
<td>0.008</td>
</tr>
<tr>
<td>Other physical injuries (yes)</td>
<td>73.9%</td>
<td>24.1%</td>
<td>25.8%</td>
<td>68.94</td>
<td>2</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Stress Symptoms (yes)</td>
<td>11.3%</td>
<td>25%</td>
<td>8.0%</td>
<td>7.46</td>
<td>2</td>
<td>.024</td>
<td></td>
</tr>
<tr>
<td>LOC (yes)</td>
<td>55.5%</td>
<td>62.1%</td>
<td>50%</td>
<td>1.87</td>
<td>2</td>
<td>.393</td>
<td></td>
</tr>
<tr>
<td>Estimated LOC duration (%)</td>
<td></td>
<td></td>
<td></td>
<td>7.64</td>
<td>4</td>
<td>.106</td>
<td></td>
</tr>
<tr>
<td>&lt;1 min</td>
<td>57.7</td>
<td>62.5</td>
<td>67.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–2 min</td>
<td>13.5</td>
<td>25.0</td>
<td>21.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;2 min</td>
<td>28.8</td>
<td>12.5</td>
<td>11.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: RTD = returned to duty; LOC = loss of consciousness; MACE = Military Acute Concussion Evaluation.
*Partial \(\eta^2\) effect sizes: small, \(>0.010\); medium, \(>0.059\); large, \(>0.138\).
Table 2. Prompt versus delayed group

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>Mean (SD)</th>
<th>t</th>
<th>df</th>
<th>p-value</th>
<th>Cohen's d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Prompt</td>
<td>24.2 (5.1)</td>
<td>-0.80</td>
<td>178</td>
<td>.425</td>
<td>0.11</td>
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<td></td>
<td>Delayed</td>
<td>24.8 (5.6)</td>
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<tr>
<td># prior non-blast concussions</td>
<td>Prompt</td>
<td>1.1 (1.8)</td>
<td>-0.92</td>
<td>167</td>
<td>.357</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>Delayed</td>
<td>1.4 (2.2)</td>
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<tr>
<td># prior blast concussions</td>
<td>Prompt</td>
<td>0.4 (0.9)</td>
<td>-1.46</td>
<td>169</td>
<td>.146</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>Delayed</td>
<td>0.6 (0.9)</td>
<td></td>
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<td></td>
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<tr>
<td>Total # prior concussions</td>
<td>Prompt</td>
<td>1.5 (2.1)</td>
<td>-1.38</td>
<td>167</td>
<td>.169</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>Delayed</td>
<td>2.0 (2.5)</td>
<td></td>
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<tr>
<td>MACE Cognitive Score</td>
<td>Prompt</td>
<td>24 (5)</td>
<td>0.68</td>
<td>132</td>
<td>.498</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>Delayed</td>
<td>23 (5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headache Severity</td>
<td>Prompt</td>
<td>5.0 (3.3)</td>
<td>-3.65</td>
<td>163</td>
<td>&lt;.001</td>
<td>0.57</td>
</tr>
<tr>
<td></td>
<td>Delayed</td>
<td>6.6 (2.2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Symptom Scale</td>
<td>Prompt</td>
<td>4.4 (2.6)</td>
<td>-4.44</td>
<td>168</td>
<td>&lt;.001</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td>Delayed</td>
<td>6.0 (2.1)</td>
<td></td>
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</tr>
<tr>
<td>Education (years)</td>
<td>Prompt</td>
<td>12.7 (1.3)</td>
<td>0.63</td>
<td>162</td>
<td>.532</td>
<td>0.08</td>
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<td></td>
<td>Delayed</td>
<td>12.6 (1.2)</td>
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<tr>
<td>Other physical injuries</td>
<td>Prompt</td>
<td>20.0%</td>
<td>3.24</td>
<td>1</td>
<td>.072</td>
<td>0.35</td>
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<td></td>
<td>Delayed</td>
<td>31.8%</td>
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</tr>
<tr>
<td>Stress Symptoms</td>
<td>Prompt</td>
<td>3.4%</td>
<td>5.17</td>
<td>1</td>
<td>.023</td>
<td>0.79</td>
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<td></td>
<td>Delayed</td>
<td>12.6%</td>
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<tr>
<td>LOC</td>
<td>Prompt</td>
<td>46.7%</td>
<td>0.81</td>
<td>1</td>
<td>.368</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>Delayed</td>
<td>53.4%</td>
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<td></td>
</tr>
<tr>
<td>Estimated LOC Duration</td>
<td>Prompt</td>
<td>65.6%</td>
<td>4.20</td>
<td>2</td>
<td>.122</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Delayed</td>
<td>15.6%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>18.8%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>68.3%</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>26.8%</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>4.9%</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Notes: LOC = loss of consciousness; MACE = Military Acute Concussion Evaluation; Cohen’s d effect sizes: small, >0.2; moderate, >0.5; large, >0.8 (estimated using OR for 2 × 2 χ² data).

Table 3. Predictors of recovery/RTD time

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>β</th>
<th>t</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear stepwise regression</td>
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<td>Symptom Scale total</td>
<td>1.261</td>
<td>0.402</td>
<td>0.277</td>
<td>3.134</td>
<td>.002</td>
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<tr>
<td>Other Physical Injuries</td>
<td>5.667</td>
<td>2.124</td>
<td>0.224</td>
<td>2.672</td>
<td>.009</td>
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<tr>
<td># Prior blast concussions</td>
<td>2.066</td>
<td>0.687</td>
<td>0.202</td>
<td>2.382</td>
<td>.019</td>
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<tr>
<td>Stress Symptoms</td>
<td>7.518</td>
<td>3.596</td>
<td>0.184</td>
<td>2.090</td>
<td>.039</td>
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<tr>
<td>Constant</td>
<td>6.169</td>
<td>2.314</td>
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<td>2.666</td>
<td>.009</td>
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<tr>
<td>Adjusted R²</td>
<td></td>
<td></td>
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<tr>
<td>SE of estimate</td>
<td>8.369</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>F</td>
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<td>df</td>
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<tr>
<td>p-value</td>
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<tr>
<td>Model</td>
<td>0.21</td>
<td>9.3</td>
<td>8.469</td>
<td>4.109</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Variable</td>
<td>B</td>
<td></td>
<td>Exp(B)</td>
<td>95% CI</td>
<td>p-value</td>
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<tr>
<td>Logistic regression (backward stepwise likelihood ratio)</td>
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<tr>
<td>Symptom Scale total</td>
<td>0.201</td>
<td>4.112</td>
<td>1.22</td>
<td>1.0–1.49</td>
<td>.043</td>
</tr>
<tr>
<td>Other Physical Injuries</td>
<td>1.718</td>
<td>10.102</td>
<td>5.58</td>
<td>1.9–16.1</td>
<td>.001</td>
</tr>
<tr>
<td># Prior blast concussions</td>
<td>0.287</td>
<td>1.699</td>
<td>1.33</td>
<td>0.9–2.1</td>
<td>.192</td>
</tr>
<tr>
<td>Stress Symptoms</td>
<td>0.201</td>
<td>4.112</td>
<td>2.54</td>
<td>0.4–15.0</td>
<td>.305</td>
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<tr>
<td>Constant</td>
<td>-1.677</td>
<td>8.006</td>
<td>0.19</td>
<td></td>
<td>.005</td>
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<td>NagR² Classifications</td>
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<td>p-value</td>
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<tr>
<td>Model</td>
<td>0.21</td>
<td>68.40%</td>
<td>19.786</td>
<td>4</td>
<td>.001</td>
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</table>
Discussion

While much of the past research on blast injuries was conducted well after the blast injury occurred, the current study provides empirical battlefield data on symptom presentation and recovery/RTD. Findings from this study suggest that blast concussion may require longer recovery times than previously realized and that LOC may not be a salient decision point. Recovery times ranged from 7.6 days in the prompt RTD group to an average of 24.4 days in the delayed RTD group with significant variability within groups. When comparing these recovery times to the sports concussion literature, recovery time appears far greater in blast concussion, which supports the notion that post-injury management must be addressed differently and RTD decisions/policy should not be based on data informing RTP following sports concussions.

Findings regarding age are difficult to evaluate. The average age of 26.8 in the non-RTD concussion group in comparison with 24.5 in the RTD group would not normally be felt to be practically significant. However, it is a finding that deserves more attention. For example, a roughly 27-year old in the infantry will usually be a senior enlisted member responsible for a significant number of junior Marines and the implementation of a variety of missions. It is likely that they have deployed several times previously and have had a variety of experiences. The difference of two and a half years of experience and rank might be practically significant and this finding should be evaluated with a larger sample size of individuals.
LOC deserves particular note. In this study, we found that the presence of LOC did not impact recovery time. A prior battlefield study (Luethcke et al., 2011) looking at both blast and non-blast concussions noted that duration of LOC was related to decreased accuracy on the ANAM, a computerized test used by the military to track concussion recovery. However, the study also found that non-blast concussions were more likely to result in LOC and longer duration of LOC, so it is unclear what impact this has on blast concussion recovery. Both LOC and the use of the ANAM with blast concussion deserve further study.

When considering mission requirements and blast concussions, military commanders must understand that service members may take considerably longer to RTD than previously thought. Current guidance in theater is that if a service member cannot RTD within 2 weeks, he/she should be returned to the states. However, this study indicates that those who exhibit acute stress symptoms at the time of the concussive injury, who endorse a greater number of acute concussion symptoms, and who endorse significant headache pain may require over 3 weeks for recovery in order to RTD. This has considerable operational relevance, and those factors that might predict probable group membership at the time of initial evaluation are extremely important to the service member, treatment facilities, and commanding officers. RTD decision-making requires careful consideration of individual risk factors on a case-by-case basis.

Interestingly, the service member’s level of acute stress was the second greatest predictor of delayed recovery/RTD behind confusion, which is not a marker traditionally relied on to classify severity of injury and/or predict RTD. This finding illustrates the importance of integrating mental health providers into post-concussive care. This care is best served throughout the entire recovery process, beginning with inpatient roles in the combat hospitals in order to intervene early when concussed service members are initially processing the incident, and then following them beyond emergency room visits and inpatient care to the outpatient setting. This will allow for early education, further normalize interactions with mental health providers, decrease the risk of symptom attribution errors and increase the likelihood of prevention of long-term mental health problems.

With regard to the MACE findings, acute evaluation of concussion on the battlefield appears best accomplished by taking a good history of the event and carefully evaluating the resulting symptom presentation, as opposed to relying on the MACE cognitive score. There does appear to be a window in which the MACE cognitive score may best reflect the sequelae of the concussive injury (within 6 h of the event) but if administered outside of this 6-h window, there is no current evidence supporting its use. Preliminary recommendations regarding MACE cognitive score administration is that if it cannot be administered within the first 6 h, the concussion evaluation should consist of history gathering (of the incident), symptom report (including the neurological screening), and pertinent characteristics of individuals (e.g., concussion history). If the cognitive portion of the MACE was administered within 6 h, a clinician may wish to readminister (an alternate form of) the MACE at a later time to document improvement.

Although this study has provided some evidence as to blast concussion presentation and recovery in theater, it is limited in that it represents a retrospective account of concussed service members on the battlefield as opposed to a prospective account. The study also consists only of service members who were sufficiently concussed/injured that the field medical asset determined that medical evacuation was the appropriate course of action. Consequently, this sample contains few individuals with mild or uncomplicated concussions and a large number of individuals with other significant physical combat injuries which required emergency surgery.

Of interest is that the predominant mechanism of injury was felt to be primary blast concussion as opposed to secondary or tertiary effects. Survey research, for example, suggests a much smaller incidence of primary blast injury (8.7%; Vanderploeg et al., in press). Consequently, it is unknown if these findings represent an accurate depiction of blast concussions or conversely represent an inference effect of the aforementioned acuity of this particular study population and/or a function of the inability to measure this phenomena without a means to objectively witness/document the events as they occur. Although great care was made to take detailed histories from the service members themselves and collateral sources (other service members present at the time, combat corpsmen/medics, field injury reports, and the chain of command) and care was made during the physical examination to look for evidence of impact to the head (e.g., abrasions, soreness, swelling, and CT of the head), it is difficult to assess the accuracy of this finding. Only further battlefield research will be able to clarify the incidence of primary versus secondary/tertiary blast concussion.

Findings regarding headache pain are interesting but difficult to apply clinically given the narrow range between groups (5.0 vs. 6.6), which may be due to the manner in which this was measured (0–10 pain scale). Likewise, combat stress was measured only via clinical interview and observation given the nature of the combat hospital setting as opposed to the use of a validated measure. Last, given the very small number of women seen following concussion (i.e., 3), all findings contained herein may only be considered representative of male service members.

This study serves to shed light on a number of problems encountered when attempting to assess blast concussion in theater. Future research should focus on continued improvement of battlefield concussion evaluations; continued exploration of the best use of the MACE; further delineation of factors which predict faster and slower recovery; and identification of the differences beyond recovery time between blast and non-blast concussion.
Conflict of Interest

None declared.

Acknowledgements

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References


