Posttraumatic Stress Disorder and Post Concussion Syndrome
in Relation to the Alcohol Use Among Members of the Armed Force Who Served in
Operation Enduring Freedom/Operation Iraqi Freedom

by

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Abstract

Alcohol use is an established behavior and a growing concern within the Active Duty Service Members and Veteran communities. Previous research has found both Posttraumatic Stress Disorder (PTSD) and Post-Concussion Syndrome (PCS) following a traumatic brain injury (TBI) are associated with increased risk of experiencing negative consequences in conjunction with alcohol use. Presently the literature does not examine the relationships among these constructs among Combat Veterans using DSM-5 criteria and validated measures of all relevant symptoms. The current study sought to investigate these relationships in a sample of 88 male combat Veterans. Pearson correlations found that PTSD and TBI symptoms were highly correlated with each other, and that PTSD positively correlated with alcohol-related symptoms. However, TBI symptoms were not correlated with alcohol-related symptoms. To determine whether PCS moderates the relationship between PTSD and alcohol-related symptoms, we conducted two regressions (i.e., total scores and subscales). When included into the models simultaneously, neither PTSD total or TBI total scores nor PTSD avoidance scores or TBI vestibular scores accounted for variance in alcohol total scores, respectively. The respective interaction terms also failed to reach significance. These findings add to the varied results of previous research on the relationship between these constructs. Findings are also discussed in terms of limitations and future directions for research.

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Introduction

Combat exposure introduces the risk of serious injury, sexual violence, and actual or threatened death which may result in Posttraumatic Stress Disorder (PTSD). Recent research estimates a PTSD prevalence rate of 13.8% among Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) Service Members (Tanielian & Jaycox, 2008). The same combat experiences that lead to PTSD can also result in physical injury to the brain, referred to as traumatic brain injuries (TBI) which impacts an estimated 23-30% of OEF/OIF veterans (Miller et al., 2013). Unfortunately, there is evidence supporting an underreporting of combat-related psychological and physical trauma and underutilization of military support services within this population (Hom et al., 2017). It has also been suggested that individuals who do not seek treatment for distressing symptoms may be engaging in less helpful coping behaviors, including alcohol use. Estimates of past-month heavy episodic drinking find that 19% of female Veterans and 51% of male Veterans exhibit risky alcohol use (Hoggatt et al., 2017). As TBI is now considered a signature injury of recent wars (i.e., OEF and OIF), additional research is required to explore how TBI and PTSD are related to alcohol use. This study will address the issue by investigating the relationship among symptoms of PTSD, TBI, and alcohol use in a sample of combat-exposed OEF and OIF Service Members.

Alcohol Use Among Active Duty Service Members and Veterans

Concerns about substance use behaviors among Active Duty Service Members and Veterans dates back over forty years as data emerged suggesting that both populations engage in heavy drinking practices (Ames et al., 2009; Bray et al., 2010; Bryant, 1979; Ingraham & Manning, 1984). Recent research finds 30% of Active Duty Service Members reported past-month binge drinking (i.e. ≥ 5 drinks on one occasion and ≥ 4 on one occasion for men and women, respectively) and 35.3% reported hazardous drinking or possible alcohol use disorder (AUD), as defined by the Alcohol Use Disorder Identification Test – Consumption (i.e., scores of ≥ 4 for men and ≥ 3 for women) (AUDIT-C, Bush et al., 1998; Meadows et al., 2018). Past-month binge drinking is also found in 19% of female Veterans and 51% of male Veterans (Hoggatt et al., 2017). More specifically, a sample of OEF and OIF Veterans reported 51% of respondents engaging in any binge drinking and 17% engaging in frequent binge drinking (Calhoun et al., 2016). Regarding clinical diagnoses, a review of clinical Veterans Affairs health records revealed that 0.5% of male and 4.8% of female Veterans who served in Iraq or Afghanistan during OEF/OIF meet criteria for current AUD (Seal et al., 2011). However, it is important to acknowledge that individuals engage in risky alcohol use and experience negative consequences in the absence of a diagnosis. To summarize, prevalence data suggests risky alcohol use is found in both Active Duty Service Member and Veteran populations.

Active Duty Service Members and Veterans suffer from negative alcohol-related outcomes across several domains. Individuals in either population who use alcohol at elevated rates are more likely to experience suicidal ideation (Gradus et al, 2013; Mash et al., 2016), insomnia (Miller et al., 2017; Short et al., 2019), aggression (Gallaway et al., 2012; Watkins et al., 2017), productivity loss and increased incidence of accidents (Santiago et al., 2010; Stahre et al., 2009). It is suggested that productivity loss stemming from negative alcohol outcomes (e.g. hurt on the job due to drinking, arriving late or leaving early due to alcohol, missing work because of an illness or injury caused by alcohol, etc.) can affect troop readiness. A survey of Active Duty Service Members across all services identified that heavy drinkers (i.e. five for more drinks per occasion at least once a week) experience almost three times more alcohol related consequences and double the rate of productivity loss than moderate/ heavy drinkers (i.e. 2 to 4 drinks per drinking occasion at least once a week or 5 or more drinks per drinking occasion 2 to 3 times per month) (Mattiko et al., 2011). Results also indicate a dose dependent relationship between drinking levels and related consequences across all categories of drinking behaviors (i.e. abstainer, infrequent/light drinker, moderate drinker, moderate/heavy drinker). Overall, research suggests heavier alcohol use effects these populations psychologically and physically.

TBI and Alcohol Use Among Active Duty Service Members and Veterans

TBI is a result of impact to the head which causes memory loss, loss of consciousness (LOC), fractures to the skull, brain lesions, or neurological malfunctions (Waxweiler et al., 1995). TBI patients experience symptoms characterized as affective, cognitive, and/or somatic with the majority of patients becoming asymptomatic within weeks (Prince & Bruhns, 2017). A minority of patients continue to experience symptoms months to years following the initial injury, which is referred to as post-concussive syndrome (PCS) (McCrea, 2008). Researchers disagree whether psychogenic factors, neurogenic factors, or a combination of both explain the persistent nature of PCS (Rees, 2003; Williams et al., 2010). For the purpose of our review, we include those with PCS when referring to TBI due to the unknown etiology of PCS symptoms.

There is ample evidence suggesting a relationship between AUD and TBI risk. Alcohol intoxication at injury onset is seen in 33-50% of those diagnosed with TBI (Parry-Jones et al., 2006) with premorbid history of SUD also reported by 18-66% of TBI patients (Corrigan & Cole, 2008). When admitted for rehabilitation, up to 50% of TBI patients meet criteria for AUD (Bombardier et al., 2003). Although it is common for the rate of alcohol consumption to decrease after hospital discharge, about 30% of TBI patients continue drinking post-injury (Bombardier et al., 2003). TBI patients who choose to drink post-injury exacerbate symptoms and impede recovery resulting in poor emotional and behavioral outcomes (Kolakowsky-Hayner et al., 2002). Due to the fact that high proportions of individuals diagnosed with a TBI are intoxicated at the time of the injury, the temporal relationship between alcohol use and TBI is currently an area of continued research interest.

There is growing concern over the co-occurring nature of TBI and risky alcohol use in Veteran and Active Duty Service Member populations. Interest in this relationship is warranted as the diagnosis is considered the signature injury of OEF and OIF (McCrea et al., 2008). Throughout Veteran and Active Duty Service Member populations, those diagnosed with TBI exhibit significantly higher rates of subsequent alcohol use than those without TBI (Grossbard et al., 2017; Johnson et al., 2015; Rona et al., 2012; Adams et al., 2012). In particular, male OEF and OIF veterans suffering with TBI exhibit higher rates of alcohol misuse (i.e. AUDIT-C ≥ 5) when compared to those without TBI (Grossbard et al., 2017). Combat Veterans are at an even higher risk for TBIs, perhaps due to nature of their deployments, and the TBI diagnosis is associated with increased drinking-related consequences and diagnoses 1-year post-injury when compared to their counterparts without a TBI diagnosis (Adams et al., 2013; Johnson et al., 2015). Further analyses indicate that Combat Veterans who sustained an mTBI accompanied by a LOC greater than 20 minutes are at an increased risk for negative alcohol-related consequences. Thus, the research suggests a strong relationship between TBI and alcohol with long-term consequences.

PTSD and Alcohol Use Among Active Duty Service Members and Veterans

Active Duty Service Members and Veterans are not only at risk for physical trauma, but also psychological trauma. PTSD currently impacts 13.8% of OEF/OIF Service Members (Tanielian & Jaycox, 2008) and is strongly associated with risky drinking patterns (i.e. alcohol misuse, binge drinking and AUD) (Jakupcak et al., 2010; Mustillo et al., 2015). Prevalence data of Veterans found 63% of treatment-seeking OEF/OIF Veterans experience comorbid AUD/PTSD (Seal et al., 2011). It may be suggested that the dangerous experiences of military service places Active Duty Service Members and Veterans at an elevated risk of developing comorbid AUD and PTSD.

Combat exposure provides for the opportunity for psychological trauma and is considered a predictor of alcohol-related consequences as well as PTSD (Hooper et al., 2008; Jacobson et al., 2008; Wright et al., 2012). Combat experience is strongly associated with various internalizing and externalizing behaviors including alcohol misuse (Green et al., 2014; Schumm & Chard, 2012; Seal et al., 2007; Wilk et al., 2010). The Millennium Cohort Study followed Active Duty Service Members pre- to post-deployment and found those who gained combat experience during deployment exhibited onsets of binge drinking and heavy drinking (Jacobson et al., 2008). There also exists a significant relationship between the amount of combat experiences and alcohol misuse (Wilk et al., 2010). Active Duty Service Members with increased combat experience exhibit significantly higher rates for endorsing alcohol misuse with notable increases for those in situations with perceived threat of death or injury. More specifically, out of all categories of combat experiences (i.e. fighting, killing, threat to oneself, death/injury of others, and atrocities) Active Duty Special Operations Soldiers engaging in “fighting” combat experiences were significantly more likely to endorse alcohol misuse (Skipper et al., 2014). As the research suggests Active Duty Service Members and Veterans who are exposed to combat are at higher risk for both PTSD and alcohol misuse.

Several theories attempt to illustrate the temporal relationship between risky alcohol use and PTSD. Some hypothesize that individuals who experience traumatic events choose to engage in hazardous alcohol use to avoid distressing symptoms. Temporary relief of PTSD symptoms is provided by alcohol which negatively reinforces and maintains this coping strategy. This theory, termed the self-medication model, considers alcohol use as a means of mitigating the undesirable effects of PTSD symptoms (Leeies et al., 2010). Unfortunately, the self-medication model does not take into account premorbid patient functioning. Other models suggest that alcohol use may serve as a risk factor for the development of PTSD symptoms. Individuals with a drinking history who are faced with a traumatic experience may continue to use alcohol with the intention of avoiding distressing PTSD symptoms. This theory, the mutual maintenance model views alcohol as an avoidance behavior which inhibits the individual from PTSD recovery, and with alcohol withdrawal symptoms worsening or acting like PTSD symptoms (Kaysen et al., 2017). As withdrawal symptoms and PTSD symptoms may overlap it makes it difficult to determine the sequence of onset found in comorbid PTSD and alcohol use. Similarly, the high-risk model characterizes alcohol use as a risk behavior which may increase the incidence of traumatic events and the subsequent development of PTSD (Windle, 1994). Unlike previous models, the third variable model accounts for comorbid PTSD and risky alcohol use as the result of shared genetic variance (Norman et al., 2012). The causal pathways of these diagnoses remain unclear due to the probable intertwined etiology of these diagnoses.

Regardless of the etiology, the comorbidity of AUD and PTSD tends to lead to symptoms that are more severe, chronic, and treatment-resistant than symptoms associated with either diagnosis on its own (McCarthy & Petrakis, 2010). OEF and OIF Veterans who report hazardous drinking and an increasing number of PTSD symptoms also report their global health as poorer than Veterans reporting fewer mental health problems (McDevitt-Murphy et al., 2010). Alcohol misuse has been found to mediate the relationship between PTSD symptoms and the psychological dimension of overall health in OEF and OIF veterans. According to a nationally representative sample of U.S. Veterans, Veterans with AUD/PTSD were more likely than Veterans experiencing AUD only to experience generalized anxiety disorder, major depression, suicidal ideation and attempts as well as current mental health treatment (Norman et al., 2018). In conclusion, individuals with comorbid AUD and PTSD experience poorer overall and mental health outcomes when compared to individuals with either diagnosis on its own.

Alcohol, TBI, and PTSD Among Active Duty Service Members and Veterans

Previous studies have firmly established that TBI and PTSD are areas of clinical concerns for Active Duty Service Members and Veterans, and that both are linked to increased risk for a range of alcohol-related negative consequences. However, the research on how comorbid TBI and PTSD relate to alcohol use outcomes is less clear. At least two studies have found that the relationship between hazardous alcohol use and TBI no longer exists after controlling for PTSD symptoms (Polusny et al., 2011; Miles et al., 2015). Polusny and colleagues (2011) examined the relationship between mTBI and PTSD symptoms along with AUDIT total scores in a longitudinal cohort study of 953 US National Guard soldiers. Participants completed surveys in Iraq 1-month prior to deployment completion and again 1- year post deployment. AUDIT total scores were significantly different between mTBI and control groups but failed to reach significance after adjusting for post deployment PCL-Military total scores. Similarly, Miles and colleagues (2015) investigated the influence of mTBI and PTSD on AUD in OEF/OIF Veterans via retrospective medical record review. Participants were interviewed as part of mandatory mental health evaluations and data was extracted from VA electronic medical records for variables of interest. Results indicated that PTSD total symptoms and age, but not mTBI symptoms, significantly predicted AUD in male Veterans. For female Veterans, neither PTSD nor mTBI symptoms predicted AUD. Both studies suggest that the relationship between TBI and alcohol use may involve or be dependent upon PTSD symptoms.

In contrast, at least one study has found the relationship between alcohol and TBI still exists even after controlling for PTSD (Johnson et al., 2015). Johnson and colleagues utilized electronic health records of Active Duty Service Members who received either outpatient or inpatient care. TBI, AUD and PTSD diagnoses were indicated via ICD-9-CM codes within each medical record. Among Active Duty Service Members, those who were diagnosed with a TBI exhibited significantly higher incidence rate ratios (IRR) for AUD when compared to those without a TBI diagnosis. After controlling for variables such as prior diagnosis of PTSD and diagnosis of PTSD during the follow-period, the IRR between TBI and AUD remained significant.

Studies on the relationships between PTSD, mTBI and alcohol use have primarily focused analyses at the level of reported diagnoses (Johnson et al., 2015; Polusny et al., 2011) or total scores on various symptoms measures (Miles et al., 2015). However, previous research has not examined these relationships at a symptom subscale level. Factor analytic studies identify the following four factors of PTSD: reexperiencing, active avoidance, numbing/passive avoidance and arousal (Palmieri et al., 2007; Palmieri & Fitzgerald, 2005). With respect to TBI symptoms using the NSI, research has identified the following four factors of TBI: somatic/sensory, affective, cognitive, and vestibular (Soble et al., 2014; Vanderploeg et al., 2015). In terms of TBI, research has found that this diagnostic population engages in numbing to alleviate distress which is a clear overlap with the PTSD avoidance subscale (Bryant, 2011). As alcohol use can be categorized as numbing/passive avoidance, the PTSD avoidance subscale is suited to investigate the relationship between alcohol use and PTSD. Although avoidance can include external reminders of the traumatic event, it can also include internal stimuli. At a subscale level, the vestibular factor of the NSI includes unique internal stimuli such as dizziness. To investigate how specific internal stimuli as a result of TBI may impact the relationship between PTSD avoidance and alcohol use, the vestibular subscale of the NSI and the avoidance subscale of PTSD should be used to investigate these relationships.

Current research does not present consistent evidence for the relationship between alcohol use, TBI, and PTSD among Active Duty Service Members and Veterans. Given the prevalence and potential severity of all three conditions, additional research is clearly warranted. One possible explanation for the inconsistency may be due to the wide variety of assessment approaches (e.g., self-report, chart review, categorical vs. dimensional) and samples (e.g., Active Duty Service Members, Veterans, with or without combat experience) each study employed. In addition, none of the reviewed studies utilize a measure of PTSD symptoms based on current diagnostic criteria (i.e., DSM-5) along with measures that assess TBI, PTSD or alcohol use symptoms in a dimensional manner. As no previous studies have used DSM-5 criteria it will be important to determine if the clarification of criterion A, the increase in the number of symptom groups and number of symptoms will have an effect on the constructs of interest (Pai et al., 2017). Similarly, assessing symptoms in a dimensional manner may capture variability that is lost with categorical approaches. Dimensional measures of alcohol use, such as the AUDIT, may be particularly useful in assessing the relationships among variables in samples of individuals who do not currently meet criteria for an AUD but may be at risk of doing so in the future. The current literature does not include a study that uses a dimensional approach to assess the relationships among PTSD, TBI, and alcohol use among a sample of Active Duty Service Members and Veterans who experienced combat during OIF/OEF.

Current Study

Prior research has investigated the relationships among mTBI, alcohol use, and PSTD among Veterans and Active Duty Service Members with conflicting results. The current study aimed to extend previous research in order to examine the relationships in a sample of OEF/OIF Active Duty Service Members and Veterans with combat experience using a set of dimensional measures to assess current mTBI, PTSD, and alcohol use symptoms. In addition, we used a PTSD measure that assesses current diagnostic criteria (i.e., DSM-5 criteria). Descriptive analyses were conducted to describe our sample and investigate bivariate relationships between measured study variables (e.g., demographics, characteristics of service, symptoms). Specific hypotheses investigated were:

Hypothesis 1: PTSD total scores and mTBI total scores will be positively correlated with risk for alcohol-related symptoms.

Hypothesis 2: mTBI and PTSD total scores will be positively correlated with each other.

Hypothesis 3: PTSD total scores will account for more variance in alcohol total scores, when both PTSD total scores and mTBI total scores are entered into the model.

Hypothesis 4: The relationship between PTSD total scores and alcohol total scores will be dependent on the value of mTBI total scores. It is hypothesized that the relationship between PTSD total scores and alcohol total scores will be stronger at higher levels of mTBI total scores.

Hypothesis 5: The relationship between the PTSD avoidance subscale and the alcohol total score will be dependent on the value of mTBI vestibular subscale. It is hypothesized that relationship between PTSD avoidance subscale and the alcohol total score will be stronger at higher levels of the mTBI vestibular subscale.

Methods

Participants

Participants were recruited as part of a more comprehensive study on the neurological effects of physical and psychological trauma (Rangaprakash et al., 2017). General inclusion criteria for all participants included being 19-50 years old; identification as Active-Duty, Reservists, or National Guard member of the Armed Forces or Veteran; and previous combat exposure during OEF and/or OIF. Individuals were excluded from the study if they met one or more of the following general exclusion criteria: severe TBI, DSM-IV-TR or DSM-5 criteria for a psychotic disorder or substance dependence/ substance use disorder; and contraindications for MRI. Individuals who met the general inclusion and exclusion criteria were then placed into the following four overlapping groups: PTSD group (n= 40), PTSD healthy control group (n= 40), TBI group (n= 40), and/or TBI healthy control group (n= 40). Individuals were included in the PTSD group if they met diagnostic criteria as assessed by the Clinicians Administered PTSD Scale (CAPS; Weathers et al., 2018). Participants were included in the PTSD healthy control group if they did not meet criteria for PTSD by the CAPS, had no history of mTBI within the last 5 years and/or current post-concussion symptoms and had no history of moderate to severe TBI. Individuals were included into the TBI group if they sustained at least 1 mTBI within the last 8 years and not within the last 3 months; TBI was experienced during OEF or OIF; loss of consciousness lasting less than 30 minutes or posttraumatic amnesia of less than 1 hour, or endorsement of current PCS symptomology. Participants were included in the TBI healthy control group if they had no history of TBI.

The total number of respondents for the study included 105 Active-Duty Service Members and Veterans. Within groups there was a considerable overlap in the number of participants. In particular, there are 9 TBI control participants, 10 PTSD control participants, 30 shared TBI and PTSD control participants, 16 TBI participants, 16 PTSD participants, and 24 TBI and PTSD participants. Due to the fact that the analyses examined the relationship between variables in a dimensional manner, the current study grouped all participants together. After examining gender distribution, power analyses indicated that the sample was underpowered to test hypotheses for both males and females. The subsequent analyses were run with 88 male participants. Participant age ranged from 23-53 years with the mean age being 32.87 years. The largest proportion of the sample identify as Caucasian (67%) followed by African American (17%), Hispanic (11.4%), Asian (2.3%), Native American (1.1%), and Other (1.1%). Additional demographic data can be found in Table 1.

Procedures

Participants were recruited via flyers and posters posted in Fort Rucker, AL and the TBI clinic at Fort Benning, GA. Recruitment materials included the phone numbers of study personnel who administered phone screens to determine the respondent's eligibility for the study using the previously described inclusion and exclusion criteria. Eligible participants were contacted by research personnel to schedule in-person appointment for the consenting process, but participants also had the option to sign consent form, HIPAA, and MRI pre-screen form by regular mail, fax or email. After consenting, PIs and study physician verified eligibility based on medical records and screening materials. Research personnel then contacted participants to schedule a session at the Auburn MRI Center and provide proof of leave or off-duty status. Participants were re-consented and asked to fill out the MRI screening form prior to completing an MRI scan. Following the completion of the MRI scan participants provided blood samples, completed behavioral measures, and self-report measures. Upon completion of all study procedures participants were compensated and discharged. Although all data (i.e., biological, MRI, behavioral measures) was available only behavioral data was used in the current study.

Measures

Demographics. This measure assessed basic demographic information and service-related variables. Variables include age, gender, race/ethnicity, pay grade, military occupational specialty code (MOS), education level in years, mother's education level, and date of last deployment.

PTSD Checklist-5 (PCL-5; Weathers, et al., 2013). Based on the diagnostic criteria from the DSM-5, the PCL-5 assesses the presence of 20 symptoms over the past month, which apply to both civilian and the military populations (Blevins et al., 2015). The PCL-5 identifies one traumatic event the respondent has experienced as the index event. The self-report rating scale provides a range of response choices: 0-Not at all, 1-A little bit, 2-Moderately, 3-Quite a bit, and 4-Extremely. Total PCL-5 scores range from 0-80, with PTSD symptom severity increasing as the total score increases (Bovin et al., 2016). The PCL-5 also identifies four different symptom domains: reexperiencing, avoidance, negative alterations in cognitions and mood, and hyperarousal. PCL-5 scores indicate strong internal consistency (α= .94-.96) and both discriminant (*r*s= .31-60) and convergent validity (*r*s= .74-.85) (Blevins et al., 2015; Bovin et al., 2016). Similarly, the current study found strong internal consistency in total (α= 0.98) and subscale scores (α= 0.93-0.95).

Neurobehavioral Symptom Inventory (NSI; Cicerone & Kalmar, 1995). In order to assess the different domains of TBI symptoms, study participants completed the Neurobehavioral

Symptom Inventory (NSI). The NSI is a 22-item self-report inventory measuring post concussive symptoms. NSI ratings are based on descriptions of the frequency of the symptom, the extent to which the symptoms result in activity disruption, and the individual's perceived need for the help with the symptom. The range of response choices range from 0-4: 0-none-rarely if ever present, 1- mild-occasionally present, but it does not disrupt my activities, 2-moderate-often present, occasionally disrupts my activities, 3- severe-frequently present and disrupts activities, and 4-very severe-almost always present and I have been unable to perform at work, school or home due to this problem. Four domains are assessed using the NSI: Somatic/Sensory, Affective, Cognitive, and Vestibular. In previous studies, the Cronbach alpha for the entire scale was 0.95 indicating a high level of internal consistency (King et al., 2012). Each of the three subscales also exhibited high degrees of internal consistency (α= 0.77-0.93) (Soble et al., 2014). Similarly, the current study found strong internal consistency for both total (α= 0.97) and subscale scores (α= 0.86-0.95).

Alcohol Use Disorder Identification Test (AUDIT; Babor et al., 2001). The World Health Organization developed this measure to assess drinking behaviors, alcohol consumption, and negative alcohol outcomes in order to provide early identification of patients who drink in ways that are potentially or currently harmful to their health (Higgins-Biddle & Babor, 2018). The self-report version was used which asks respondents to recall their use of alcoholic beverages and related consequences in the past year. The AUDIT can be divided into three separate domains: Hazardous Alcohol Use, Dependence Symptoms, and Harmful Alcohol Use (Higgins-Biddle & Babor, 2018). Internal consistency for this measure is exceptionally strong (α= .96-.97) (Leung & Arthur, 2000). Similarly, the current study found strong internal consistency (α= 0.86).

Data Analysis

In order to test the first and second hypotheses (i.e., PTSD total scores and mTBI total scores are positively correlated with risk for alcohol-related symptoms; mTBI and PTSD total scores are positively correlated with each other), Pearson correlations were computed for the PCL-5, NSI, and AUDIT total scores. To test the third hypothesis for total scores (i.e., PTSD total scores account for more variance in alcohol total scores, when both PTSD total scores and mTBI total scores are entered into the model), multiple regression analyses were conducted. The fourth hypothesis (i.e., relationship between PTSD total scores and alcohol total scores are stronger at higher levels of mTBI total scores) was tested with multiple regression analyses, and significant interactions were to be probed using simple slopes analysis (Aiken & West, 1991). To investigate the fifth hypothesis (i.e., relationship between PTSD avoidance subscale and the alcohol total score are stronger at higher levels of the mTBI vestibular subscale), multiple regression analyses were conducted and significant interactions were to be probed using simple slopes analysis (Aiken & West, 1991).

Prior to analyses, researchers searched for missing values. A total of nine participants were not included into analyses for the following reasons: assigned subject id with no entered data (n= 1), no data for the variables of interest (n= 4), and neither gender or age data (n= 4). The following analyses were performed on sample of 88 male participants. Preliminary analyses included the computation of means and standard deviations for mTBI symptom total scores, mTBI vestibular symptom scores, PTSD symptom total scores, PTSD avoidance symptom scores, and alcohol symptom total scores. Prior to analysis for both regression models, log transformations were performed for highly skewed variables (i.e., AUDIT total scores; NSI vestibular subscale), predictor variables were mean-centered, and the two interaction terms (i.e., NSI total x PCL-5 total; NSI vestibular x PCL-5 avoidance) were created by multiplying the mean-centered value of NSI by the mean-centered value of PCL-5 (Aiken & West, 1991). Predictors were entered into the model simultaneously. For possible significant interactions, simple slopes analysis (Aiken & West, 1991) were to be conducted to determine the relation between PCL-5 and AUDIT a both high and low (i.e., 1 SD above and below the mean) levels of NSI.

Results

Means, standard deviations, and correlations for primary study variable can be found in Table 2. In order to test the first and second hypotheses, bivariate correlations for mTBI, PTSD, and alcohol-related symptoms were conducted. As hypothesized, PTSD total symptom scores were positively correlated with alcohol-related symptoms ($r = .22$, $p < .05$). Similarly, PTSD total symptom scores and mTBI total symptoms scores exhibited a significant positive correlation ($r = .90$, $p < .001$). However, mTBI total symptoms scores were not significantly correlated with alcohol-related symptoms ($r = .18$, $p = .09$). Additional correlations between subscales of each instrument (i.e., AUDIT, NSI, and PCL-5) were conducted. PCL-5 total and subscales were significantly correlated with AUDIT total, NSI total and subscales. Interestingly, the AUDIT total scores were only significantly correlated with PCL-5 total scores and negative cognitions and mood subscale, NSI affective subscale and cognitive subscale.

Moderating effects of mTBI symptoms on the relationship between PTSD and alcohol were investigated through two multiple regression models (i.e., one for total scores and the second for subscale scores) where all predictors were entered into the model simultaneously. The first regression model examined the moderating effects of mTBI total symptom scores on the relationship between PTSD symptom total scores and alcohol-related total symptom scores.

Tests of multicollinearity were performed which indicated multicollinearity concerns (mTBI total, Tolerance = .17, VIF = 5.84; PTSD total, Tolerance = .19, VIF = 5.39) based on elevated VIF scores for both mTBI and PTSD (Kutner et al., 2004). Contrary to our hypothesis, the overall model did not reach significance ($F(3,84)= 1.34$, $p = 0.27$) with the selected predictor explaining 4.6% of the variance. Both mTBI total symptom scores and PTSD total symptom scores failed to reach significance ($\beta = -0.437$, $p= 0.094$; $\beta = 0.477$, $p= 0.057$) and no significant interaction was identified ($\beta = -0.012$, $p= 0.918$).

The second model investigated the moderating effects of mTBI vestibular symptoms on the relationship between PTSD avoidance symptoms and alcohol-related total symptom scores. Tests of multicollinearity were performed (NSI vestibular, Tolerance = .59, VIF = 1.69; PTSD avoidance, Tolerance = .04, VIF = 26.73), which indicated multicollinearity concerns for the PTSD avoidance subscale (Kutner et al., 2004). Inconsistent with our hypothesis, the overall model did not reach significance ($F(3,84)= 1.73$, $p = 0.167$) with the selected predictor explaining 5.8% of the variance. Both mTBI vestibular symptom scores and PTSD avoidance symptom scores failed to reach significance ($\beta = -0.116$, $p= 0.402$; $\beta = -0.644$, $p= 0.243$) and no significant interaction was identified ($\beta = -0.801$, $p= 0.125$). See Table 3 for regression results.

Discussion

The current study aimed to extend previous findings on the relationship between PTSD, mTBI and alcohol use in a sample of combat Active Duty Service Members and Veterans. Furthermore, this study focused on these relationships using total scores and particular subscales from a set of psychometrically sound measures. Findings offered mixed support for the hypotheses. Consistent with hypothesis 1, alcohol-related symptom scores were significantly correlated with PTSD total symptoms. However, inconsistent with hypothesis 1, alcohol related symptoms were not correlated with mTBI total symptom scores. Consistent with hypothesis 2, mTBI was significantly correlated with PTSD total scores. Regarding hypothesis 3, neither mTBI nor PTSD total scores significantly accounted for any variance in alcohol total scores. In addition, neither the total (i.e., hypothesis 4) nor subscale (i.e., hypothesis 5) models found that mTBI moderated the relationship between PTSD and alcohol. The results of the current study are inconsistent with previous findings that show a strong relationship between PTSD and alcohol use (Jakupcak et al., 2010; Mustillo et al., 2015). The results also fail to clarify the mixed findings on the role TBI plays in accounting for alcohol use when controlling for PTSD (Johnson et al., 2015; Miles et al., 2015; Polusny et al., 2011). Additional details on the results of the current study, along with methodological concerns that impact their interpretation, are presented below.

The current study's findings diverge from the literature's understanding of mTBI, PTSD, and alcohol use. This divergence may be due to general methodological concerns, including restricted range for the AUDIT and small sample size. Participants who met criteria for DSM-IV-TR substance abuse or dependence or DSM-5 substance use disorders were excluded from the study. Although the researchers found what may appear to be an acceptable range of AUDIT scores (range = 0-34), the average score on the AUDIT (M= 6.49, SD = 6.64) indicates that the majority of participants (i.e., 67.4%) fall below the cut off of 8 for hazardous or harmful alcohol use (Babor et al., 2001). The only study to assess these relationships using the AUDIT to assess alcohol was conducted by Polusny et al., (2011). The average AUDIT scores in their mTBI (M= 9.80, SD= 7.10), PTSD (M= 12.5, SD= 9.60) and combined mTBI/PTSD groups (M= 15.2, SD= 9.30) were considerably higher compared to the current study's sample. In particular, the current study's average AUDIT score (M= 6.49, SD = 6.64) is most similar to the control group (M=

7.20, *SD* = 5.40) found in the Polusny study. In addition, while the Miles et al. (2015) study did not use the AUDIT, they did report that close to 20% of their sample met criteria for an alcohol use disorder. In light of these comparisons, the current study's sample exhibited a restricted AUDIT range and less severe alcohol use in general. Due to the fact that the current study used a restricted range of AUDIT scores to conduct analyses, it is possible that the true relationship between PTSD, mTBI and clinically significant alcohol use may not have been captured in this sample (Bland & Altman, 2011).

These divergent results may also be due to a lack of statistical power. Upon further examination, the variance explained by the regression using total symptom scores (R^2 =.05) is close to the variance (R^2 = .08) found in Miles et al. (2015) when mTBI status and PTSD total scores were used to predict AUD diagnosis. However, the Miles study conducted analyses using a more than adequate amount of participants (*N*= 1,278) as opposed to the current study's sample (*N*= 88). Low statistical power reduces the chance of identifying a true effect and accurately estimating effect sizes (Button et al., 2013). It is possible that a larger sample size would have yielded significant findings given the size of the Pearson correlations and the overall amount of variance explained. Thus, based on the restricted range of AUDIT scores and the relatively small sample size and resulting potential lack of statistical power, the results reported for hypotheses 1, 3, 4, and 5 should be interpreted with caution.

Regarding hypotheses 1, the research literature consistently finds alcohol use and related risk symptoms are associated with other types of symptoms including PTSD and mTBI. More specifically, with increasing PTSD symptoms there is an increase in alcohol use among OEF and OIF Veterans (McDevitt-Murphy et al., 2010). In addition, Active Duty Service Members and Veterans diagnosed with TBI engage in higher rates of alcohol use compared to counterparts without TBI (Grossbard et al., 2017; Johnson et al., 2015; Rona et al., 2012; Adams et al., 2012). To further investigate these relationship Pearson correlations were conducted. In line with the literature, the current study finds PTSD total symptom scores were positively correlated with alcohol-related symptoms. However, mTBI total scores were not significantly correlated with alcohol total scores. As noted above, the lack of a relationship between alcohol use and mTBI symptoms may be due to concerns about range restriction for the AUDIT. In addition, there may be concerns about the use of the NSI as a measure of TBI symptoms. Previous work by King et al. (2012) found that NSI total scores were more strongly related to affective measures (i.e., BAI and BDI-2) than to probable TBI diagnoses. In addition, researchers found that the pattern of NSI scores was higher in groups with TBI and another condition, and for non-TBI diagnostic groups, than the group with TBI alone. Thus, the NSI may not be the best tool for assessing the relationship between mTBI symptoms and alcohol. Conducting future analyses with different TBI measures is warranted.

PTSD and mTBI measures assess the presence of trauma, psychological and/or physical. Consistent with the current study's second hypothesis, PTSD total symptom scores and mTBI total symptom scores exhibit a strong positive relationship. Previous research with similar samples has also found strong positive correlations between mTBI and PTSD, but none as strong as the relationship ($r = .90$) found in the current study (Avallone et al., 2018; Porter et al., 2018; Waldron-Perrine et al., 2014). In a sample of OEF/OIF/OND combat Veterans ($N = 126$), Avallone et al., (2019) assessed the relationship between the NSI and CAPS ($r = .62$, $p < .01$). Similarly, Porter and colleagues (2018) recruited OEF/OIF/OND combat Veterans ($N = 218$) and found a positive relationship between the NSI and PCL-S ($r = .77$, $p < .01$). Lastly, Waldron-Perrine et al., (2014) conducted a retrospective review of a Midwest VA polytrauma/TBI clinic

(N= 200) and reported a strong correlation (r=.68, p< .001) between the NSI and PCL-M. Although the correlation between mTBI and PTSD exhibits a strong positive relationship, the current study's estimate still exceeds previous studies and warrants further examination.

There are several differences between studies which might explain the stronger relationship in the current study. One possible explanation is the difference in sample size. The current study conducted analyses on 88 male OEF/OIF combat Veterans as opposed to previous samples ranging from 126 to 218 participants (Avallone et al., 2019; Porter et al., 2018; Waldron-Perrine et al., 2014). Although the sample sizes are not drastically different, it is important to note that estimates become more stable as sample size increases (Schönbrodt & Perugini, 2013). In addition, the samples of previous studies included female participants (Avallone et al., 2018; Porter et al., 2018; Waldron-Perrine et al., 2014), whereas the current study only used male participants. Finally, the current sample was collected as part of a larger study which recruited participants into the following groups: TBI group, TBI healthy group, PTSD group, and PTSD healthy group. In order to examine the relationships between mTBI, PTSD, and alcohol-related symptoms, these groups were collapsed. Due to the overlap between PTSD and TBI groups, it is possible this strategy over-represented psychopathology and led to an inflated correlation between PCL and NCI scores.

It is unclear how the recruitment strategy and the relatively small and homogeneous sample impacted the relationships between PTSD and TBI symptoms in the current study. Regardless of the explanation behind the strong relationship, it does raise concerns about multicollinearity. Multicollinearity occurs when variables are highly correlated (Tabachnik & Fidell, 2013). This strong relationship indicates redundancy in the model which increases the size of errors terms and weakens the statistical analysis (Tabachnik & Fidell, 2013). As the standard error of coefficients increases this also renders the estimates unstable (Daoud, 2017). These concerns are reflected in the tolerance and VIF statistics presented for the regression analyses in the results section (see hypothesis 3 and 4). Due to the instability of estimates and weakened power of the analyses caused by multicollinearity, the results of hypothesis 3 and 4 should once again be interpreted with caution.

Similar non-significant results were found for the mTBI vestibular subscale and PTSD avoidance subscale with respect to alcohol total scores (i.e., hypothesis 5). The relationship between these subscales (r = .55, $p < .001$) is strong, but does not interfere with interpretation of the model (see hypothesis 5 multicolinearity statistics). These findings may be interpreted with a higher level of confidence due to a lack of multicollinearity between explanatory variables, although concerns about sample size and limited statistical power remain.

Limitations

The strengths of the current study are notable, including the use of dimensional measures and DSM-5 criteria in a sample of combat OEF/OIF Active Duty Service Members and Veterans. With respect to limitations, there are several to consider. As previously mentioned, exclusion of possible participants with a substance use disorder and limited power impact the interpretation of the results. In addition, using only male participants limits the generalizability of the findings. Although the cross-sectional nature of the study allowed for an investigation of moderation effects, causal interpretations cannot be made.

Another significant limitation is the use of self-report measures. Although the current study used reliable and valid measures, self-report may have contributed to method error. As self-report measures require intact memory and sustained attention (Short et al., 2009) it is possible for participants to input skewed or false data. More specifically, the current study used self-report measures to assess PTSD symptoms. Although participants were originally screened and randomized based on the CAPS-5, the data collected from the CAPS-5 were not included in the current dataset. The CAPS-5 is widely considered the benchmark of PTSD assessment and diagnosis (Weathers et al. 2018). Utilizing an extensively validated and used measure, such as the CAPS-5, may have yielded a more accurate depiction of the relationship between mTBI, PTSD, and alcohol use.

Future Directions

In light of the findings, future research should address the previously mentioned methodological concerns. Researchers should ensure subsequent studies recruit the number of participants necessary to achieve proper statistical power for proposed analyses. In addition, future samples should include both males and females to allow for generalizable findings. In regard to study criteria, samples should not exclude participants who meet criteria for alcohol use disorder to collect data from the full range of alcohol users. In terms of design, longitudinal studies as opposed to cross-sectional will allow for casual interpretations of relationship between mTBI, PTSD, and alcohol use. Furthermore, the use of clinician-administered interviews will reduce possible method bias stemming from self-report measures. Gold standard assessments, such as the CAPS should be used in screening and utilized for subsequent analyses. Lastly, future studies should consider the use of other mTBI assessments (i.e., Glasgow Coma Scale or length of Post Traumatic Amnesia) to determine whether other current assessment tools may be better suited to examine the relationship between mTBI, PTSD, and alcohol use.

Future studies would not only improve the quality of inferences made in this area; it would also provide impactful clinical insights. Subsequent research could inform health professionals about the interplay between mTBI, PTSD, and alcohol-related symptoms among

OEF/OIF Veterans. Providers may be alerted to how these symptoms relate to one another informing case conceptualization and treatment decisions. More specifically, mTBI symptoms may masquerade as PTSD symptoms and vice versa. Determining which symptoms are attributed to specific diagnoses would inform treatment. Continued assessment of these symptoms in clients would also provide data on the course and chronicity of symptoms during treatment. As previously mentioned mTBI is the signature injury of OEF/OIF (McCrea et al., 2008). More research is needed to determine how mTBI, PTSD, and alcohol use interact with each other in the OEF/OIF Veteran population.

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Appendix

Table 1
Demographic Characteristics

	Percentage (%)
Age	
23-25	17.4
26-30	19.5
31-35	30.5
36-40	17.4
41-45	10.9
46-50	3.3
51-53	1.1
Race	
Caucasian	67.0
African American	17.0
Hispanic	11.4
Asian	2.3
Native American	1.1
Other	1.1
Education (years)	
< 12	2.3
12	17.0
13-16	68.1
17-20	12.5
Mother's Education (years)	
< 12	6.8
12	50.0
13-16	23.9
17-20	19.3
Year of Deployment	
2002-2005	9.5
2006-2010	58.1
2011-2013	32.4
Pay Grade (monthly)	
1700-3000	72.4
3001-4300	17.2
4301-5600	2.3
5601-6900	6.9
6901-8200	1.2

Note. Pay grades are based on 2012 military pay charts.

Table 2

Descriptives and Bivariate Correlations for the Alcohol, PTSD, and mTBI Symptoms

	Mean	SD	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Alcohol total	6.64	6.64	-										
2. PTSD total	31.81	24.98	.22*	-									
3. PTSD intrusion	7.76	6.51	.07	.92***	-								
4. PTSD negative	10.36	9.34	.25*	.95***	.81***	-							
5. PTSD avoid	3.35	2.88	.16	.88*	.87***	.78***	-						
6. PTSD arousal	10.33	8.07	.27	.94***	.79***	.86***	.76***	-					
7. MTBI total	27.43	22.16	.18	.90***	.74***	.87***	.74***	.89***	-				
8. MTBI affect	10.53	8.29	.27*	.91***	.77***	.89***	.73***	.91***	.96***	-			
9. MTBI cog	6.65	5.33	.22*	.84***	.67***	.82***	.66***	.86***	.92***	.89***	-		
10. MTBI somatic	6.27	6.17	.05	.77***	.69***	.72***	.69***	.76***	.91***	.80***	.74***	-	
11. MTBI vest	1.74	2.33	-.01	.63***	.55***	.79***	.55***	.63***	.79***	.66***	.64***	.77***	-

Note. Alcohol total = alcohol total score; PTSD total = PTSD total score; PTSD intrusion = PTSD intrusion subscale; PTSD negative = PTSD negative cognition and mood subscale; PTSD avoid = PTSD avoidance subscale; PTSD arousal = PTSD arousal and reactivity subscale; MTBI total = mTBI total score; MTBI affect = mTBI affective subscale; MTBI cog = mTBI cognitive subscale; MTBI somatic = mTBI somatic; MTBI vest = mTBI vestibular subscale; * $p < .05$, *** $p < .001$.

Table 3

Regression Results Using Alcohol-Related Symptom Total Scores as the Criterion

Predictor	*B*	SE *B*	β	*t*	R^2
Hypothesis 3 and 4					.05
mTBI total	-.01	.01	-.44	-1.70	
PTSD total	.01	.01	.48	1.93	
mTBIxPTSD	< .001	.00	-.01	-0.10	
Hypothesis 5					.06
mTBI- vestibular	-.148	.18	-.12	-.85	
PTSD- avoidance	-.094	.08	-.65	-1.18	
VestibularxAvoidance	-.082	.05	-.80	-1.55	

Note. Hypothesis 3 = PTSD total scores will account for more variance in alcohol total scores, when both PTSD total scores and mTBI total scores are entered into the model; Hypothesis 4 = relationship between PTSD total scores and alcohol total scores will be dependent on mTBI total scores at -1 and +1 SD of the mTBI total score mean; mTBIxPTSD = interaction term of mTBI total and PTSD total; Hypothesis 5 = relationship between PTSD avoidance subscale and the alcohol total score will be stronger at higher levels of the mTBI vestibular subscale; VestibularxAvoidance = interaction term of mTBI vestibular and PTSD avoidance.