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Occupation and Risk of Traumatic Brain Injury in the Millennium Cohort Study

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Abstract

Introduction: Traumatic brain injury (TBI) is an occupational health hazard of military service. Few studies have examined differences in military occupational categories (MOC) which take into consideration the physical demands and job requirements across occupational groups.

Methods: This study was approved by the University of Texas Health Science Center at Houston Institutional Review Board. Data for this cross-sectional study were obtained from the Naval Health Research Center's Millennium Cohort Study, an ongoing DoD study. Univariate analyses were employed to calculate frequencies and proportions for all variables. Bivariate analyses included unadjusted odds ratios (OR) and 95% CI for the association between all variables and TBI. Multivariable logistic regression was used to calculate adjusted ORs and 95% CIs to assess the association between MOC and TBI, adjusted for potential confounders: sex, race/ethnicity, rank, military status, branch of service, before-service TBI, and panel. Logistic regression models estimated odds of TBI for each MOC, and stratified models estimated odds separately for enlisted and officer MOCs.

CONFLICT OF INTEREST STATEMENT

None declared.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Military Medicine* online.

Results: Approximately 27% of all participants reported experiencing a service-related TBI. All MOCs were statistically significantly associated with increased odds of service-related TBI, with a range of 16 to 45%, except for "Health Care" MOCs (OR: 1.01, 95% CI 0.91-1.13). Service members in "Infantry/Tactical Operations" had the highest odds (OR: 1.45, 95% CI 1.31-1.61) of service-related TBI as compared to "Administration & Executives." Among enlisted service members, approximately 28% reported experiencing a service-related TBI. Among enlisted-specific MOCs, the odds of TBI were elevated for those serving in "Infantry, Gun Crews, Seamanship (OR: 1.79, 95% CI 1.58-2.02)," followed by "Electrical/Mechanical Equipment Repairers (OR: 1.23, 95% CI 1.09-1.38)," "Service & Supply Handlers (OR 1.21, 95% CI 1.08-1.37)," "Other Technical & Allied Specialists (OR 1.21, 95% CI 1.02-1.43)," "Health Care Specialists (OR 1.19, 95% CI 1.04-1.36)," and "Communications & Intelligence (OR: 1.16, 95% CI 1.02-1.31)," compared to "Functional Support & Administration." Among officer service members, approximately 24% reported experiencing a service-related TBI. After adjustment the odds of TBI were found to be significant for those serving as "Health Care Officers" (OR: 0.65, 95% CI: 0.52-0.80) and "Intelligence Officers" (OR: 1.27, 95% CI: 1.01-1.61).

Conclusions: A strength of this analysis is the breakdown of MOC associations with TBI stratified by enlisted and officer ranks, which has been previously unreported. Given the significantly increased odds of service-related TBI reporting within enlisted ranks, further exploration into the location (deployed versus non-deployed) and mechanism (e.g., blast, training, sports, etc.) for these injuries is needed. Understanding injury patterns within these military occupations is necessary to increase TBI identification, treatment, and foremost, prevention.

Results highlight the importance of examining specific occupational categories rather than relying on gross categorizations, which do not account for shared knowledge, skills, and abilities within occupations. The quantification of risk among enlisted MOCs suggests a need for further research into the causes of TBI.

INTRODUCTION

From 2000 to 2021, an estimated 449,026 U.S. military service members experienced a traumatic brain injury (TBI) while serving on active duty.[1] Studies have suggested that the prevalence of TBI in military service members was between 12% and 23%,[2-5] with 80% of military TBI categorized as mild TBI (mTBI).[2-4] TBI has been considered the "signature injury" of the post 9/11 conflicts in Iraq and Afghanistan.

Military service members are organizationally categorized as officers or enlisted service members, with officers serving in leadership roles while enlisted members serve in more technical roles, receiving training for their specific occupations.[6] Officer ranks are senior to those of enlisted ranks. When examined in their broad occupational categories (enlisted versus officer) and rankings, enlisted service members were found to be at 2.2[7] to 2.3[8] times greater risk of incident TBI compared to officers. A retrospective cohort analysis of medically diagnosed mTBI from the Defense Manpower Data Center found that as rank decreased within each group, the relative risk of TBI increased significantly for junior officers (RR: 1.10; 95% CI: 1.02-1.18), senior enlisted (RR:1.61; 95% CI: 1.51-1.72), and junior enlisted (RR: 2.29; 95% CI: 2.13-2.45) service members compared to senior officers.

To date, no studies have considered specific job tasks and physical demands within each of these groups as possible risk factors for TBI. The DoD has a standardized method for defining occupations as military occupational codes (MOCs) across all military branches. The MOCs are combined based on the knowledge, skills, and abilities (KSAs), including physical demands, of an occupation.[9-11] MOCs are multi-structured, with the broadest category including Occupational Area (e.g., Infantry, Gun Crews, and Seamanship Specialists; Tactical Operations Officers), followed by Occupational Group and Occupational Subgroup. Although enlisted and officer service members work in the same units, and may have similar job titles, their job tasks and responsibilities are different. Enlisted service members cannot serve in the same MOC as officers and vice versa.

Two studies have considered MOCs when examining TBI risk, but both combined MOCs into broader risk categories rather than examining them independently to determine if differences in TBI risk existed.[7,8] For example, Cameron et al. (2012) categorized six MOCs (i.e., infantry, gun crews, and seamanship specialists, ordnance disposal and driving, law enforcement, “fixed-wing fighter and bomber pilots,” “helicopter pilots,” and “ground and naval arms”) into “combat and direct support” versus all other occupations.[8] This study observed that MOCs combined into combat and direct support were at an increased risk (RR: 1.19, 95% CI: 1.17-1.21) compared to all other MOCs. Similarly, Williams et al. categorized MOCs into combat-specific, but did not specify which MOCs were included.[7] They compared this group to other newly defined groups and observed that the combat-specific group had the highest TBI rate compared to the other groups. While these studies are informative, they failed to illustrate the risk of TBI across specific occupational groups that have different physical demands and work requirements that may place them at varied TBI risk.

A 2016 descriptive study of surveillance data using MOCs reported that those with the greatest number of head-related injuries between 2001 and 2010 had significant overlap in KSAs, including physical demands of the job. The MOCs with the most overlap were found to be Infantry, Armor and Amphibious, Combat Engineering, Artillery and Gunnery, and Combat Operations Control, some of the most physically demanding occupations.[12] These findings suggest that grouping workers by KSAs may lead to better identification of occupations at risk for TBI. However, this study provided only descriptive statistics in these by MOC, leaving a critical knowledge gap regarding the relationship between MOC and TBI.

TBI risk across occupational groups that have different physical demands and work responsibilities has not been thoroughly examined. The purpose of this study was to examine the relationship between MOCs and TBI prevalence among active duty and reserve/national guard service members in the Millennium Cohort. We hypothesized that (1) service members assigned to high physically demanding MOCs would have higher odds of TBI relative to those in less physically demanding MOCs, and (2) that enlisted members, who have more physically demanding jobs, would have a higher prevalence of TBI than officers, regardless of MOC assignment.

METHODS

Study Sample

Data for this cross-sectional study were obtained from the Naval Health Research Center's (NHRC) Millennium Cohort (MilCo) Study, an ongoing DoD study. Detailed sampling and recruitment methods are described elsewhere.[13-17] In brief, MilCo enrollment began in 2001, with a new round of service members, ages 18 years or older, recruited in panels every 3 years until 2011, when a total of four panels had been recruited.[17,18] Panel 1 recruitment began in 2001 and targeted service members regardless of their time in service. Panels 2 through 4 specifically recruited service members in their first 5 years of service. This study utilized data from the most recent survey conducted in 2014, which was the first to assess TBI. For inclusion in these analyses, service members needed to be on active duty service (not veterans separated from all military service) with complete TBI data and needed to be occupationally qualified (i.e., could not be classified as a patient or prisoner). There were 112,655 MilCo participants who completed the 2014 survey, 40,385 (35.8%) still serving on active duty or reserves/national guard at the time of the survey including 11,099 (27.5%) from panel 1, 5,100 (12.6%) from panel 2, 8,565 (21.2%) from panel 3, and 15,621 (38.7%) from panel 4.

Data Collection

MOC was ascertained from a survey question asking participants about their primary DoD occupational code, which group similar occupations across all services into a logical and consistent structure. Building on other published methodologies,[19,20] MOCs were combined and collapsed under DoD Occupational Groups with similar occupational knowledge, skills, abilities, and physical demands (e.g., "Infantry, Gun Crews, & Seamanship Specialists [Enlisted]" combined with "Tactical Operations Officers [Officer]" to create "Infantry/Tactical Operations") while keeping enlisted and commissioned officer MOCs separated (Supplemental Digital Content 1-3). For the analysis of Enlisted MOCs, the "Functional Support and Administration" MOC served as the referent category, while the "Administrators" served as a commissioned officer, hereafter referred to as officer, referent MOC as these categories are associated with reduced physical duty requirements.[6,21-23] Participants missing data for MOC were excluded from the analysis.

Assessment of service-related TBI, the main outcome, was done in two steps. First, MilCo participants were asked the following questions: "Have you ever had an injury, such as from a fall, blow to the head, blast exposure, motor vehicle crash, sports, or any other cause that resulted in any of the following: (a) Being dazed or confused right after the injury?; (b) Being confused or not thinking clearly right after the injury?; (c) Not remembering the actual injury right after it happened?; (d) Not remembering things that happened right after the injury?; and/or (e) Losing consciousness or being knocked out?" Participants were categorized as ever having a TBI if they answered "yes" to any of these questions. Second, those that experienced a TBI were asked the number of times they experienced this during military service. If they answered with any count of 1 or greater, they were categorized as "yes," having experienced service-related TBI, the outcome. If they answered with a

count of zero, they were categorized as “no,” having not experienced a service-related TBI. Participants missing data for TBI outcomes were excluded from the analysis.

Covariates included age, sex (male/female [referent]), and race/ethnicity (White [referent], Black, Hispanic, Asian/Pacific Islander, and American Indian/Other), military rank (enlisted/officer [referent]), military status (active duty, reserve/national guard [referent]), military branch (Army, Air Force [referent], Coast Guard, Marine Corps, Navy), and survey panel (1, 2, 3, or 4 [referent]). Participants were also asked the total count of TBIs they experienced prior to military service, which was collapsed into three categories (0 [referent], 1, and 2+).

Statistical Analyses

Statistical analyses were conducted using R statistical software (R Core Team, Vienna, Austria).[24] Univariate analyses were employed to calculate frequencies and proportions for all variables. Bivariate analyses included unadjusted odds ratios (OR) and 95% CI for the association between all variables and TBI. Multivariable logistic regression was used to calculate adjusted ORs and 95% CIs to assess the association between MOC and TBI, adjusted for potential confounders: sex, race/ethnicity, rank, military status, branch of service, before-service TBI, and panel. Covariates were evaluated for inclusion in the model following Hosmer and Lemeshow’s model-building strategy for logistic regression.[25] Univariate analyses and panel-specific models (findings not displayed) demonstrated the age variable did not change estimates. Further, age was collected at the time of the survey rather than at the time of injury. Given this information, the decision was made to include the panel variable as a proxy for time at risk during military service and to drop the age variable from all final models.

Tests for effect measure modification and interactions between TBI and covariates were insignificant. Finally, model diagnostics were conducted. A marginal model plot of the response variable against the linear predictor visually demonstrated the model to be a good fit for the data. A review of influential plots identified three potential outliers. Removal of outliers and comparison of models with and without these observations demonstrated no significant differences between the models. Additionally, Bonferroni’s outlier test was not significant, indicating no influential observations affected the model. The Hosmer–Lemeshow Goodness-of-Fit test was not statistically significant ($P = .23$), indicating the model adequately fits the data. Receiver operating curve showed the final model (Table III) to have fair discrimination (AUC: 76.8%, 95% CI 76.2%-77.4%).

We employed these same analytical methods to examine models stratified by enlisted and officer MOCs. For enlisted MOCs, the Hosmer–Lemeshow Goodness-of-Fit test was not statistically significant ($P = .13$), indicating the model adequately fits the data. Receiver operating curve showed the final model to have fair discrimination (AUC: 77.0%, 95% CI 76.3%-77.7%). For officer MOCs, the Hosmer–Lemeshow Goodness-of-Fit test was not statistically significant ($P = .21$), indicating the model adequately fits the data. The receiver operating curve showed the final model to have fair discrimination (AUC: 76.9%, 95% CI 75.8%-78.0%).

RESULTS

Of the 40,385 active service members surveyed in 2014, 5,336 (14.5%) were missing MOC, 533 (1.3%) were missing TBI data, and 870 (2.2%) which were not assigned to an occupational category (e.g., students, prisoners, patients). Our final analytical sample included 33,646 (83%) MilCo participants, with 9,208 (27.4%) from panel 1, 4,163 (12.4%) from panel 2, 7,253 (21.6%) from panel 3, and 13,022 (38.7%) from panel 4.

Demographic details for the sample are included in Table I. Except for age at the time of the survey, no substantial differences were observed by the panel. The average age of the sample was 37.3 (SD = 7.7) years, with participants being predominately male (71.6%), White (73.0%), enlisted (70.4%), and on active duty status (65.4%), with a little over a third of participants coming from panel 4 (38.7%), and serving in the Army (41.2%). Most of the sample worked in the following MOCs: “Electronic Repair and Engineering” (20%), “Infantry/Tactical Operations” (18.9%), “Craftworkers and Supply” (15.6%), “Administration and Executives” (13.4%), “Health Care” (13.4%), “Communications and Intelligence” (12.4%), and “Technical and Professional” (6.4%).

Approximately 27% of all participants reported experiencing a service-related TBI. The distribution of MOCs for combined enlisted and officer occupations with unadjusted odds for service-related TBI are displayed in Table II. The odds of service-related TBI were highest for those service members in “Infantry/Tactical Operations” MOCs (OR: 1.49, 95% CI 1.37-1.62) as compared to those in “Administration & Executives.” Statistically significant increased odds of reporting a service-related TBI were also found for “Craftworkers & Supply (OR: 1.20, 95% CI 1.10-1.32),” “Communications & Intelligence (OR: 1.19, 95% CI 1.08-1.31),” and “Technical & Professional (OR: 1.13. 95% CI 1.01-1.27),” MOCs as compared to “Administration & Executives.” While there was an elevated risk of service-related TBI for “Electronic Repair & Engineering (OR: 1.06, 95% CI 0.97-1.16),” this risk was not statistically significant. Those service in “Health Care” MOCs were also not at increased risk (OR: 0.99, 95% CI 0.90-1.09).

In the adjusted analysis (Table III), the odds of service-related TBI were statistically significantly lower for Black (OR 0.76, 95% CI 0.69-0.84) and Asian/Pacific Islander (OR 0.82, 95% CI 0.73-0.92) service members as compared to White service members. Service members who reported one TBI prior to military service had five times the odds of reporting a service-related TBI (OR 5.14, 95% CI 4.77-5.53) and those who reported two or more prior to service TBIs had over 10 times the odds (OR: 10.55, 95% CI 9.71-11.45) of reporting a service-related TBI as compared to those service members with no previous history of TBI. All MOCs were statistically significantly associated with increased odds of service-related TBI, with a range of 16 to 45%, except for “Health Care” MOCs (OR: 1.49, 95% CI 0.91-1.13). Service members in “Infantry/Tactical Operations” had the highest odds (OR: 1.45, 95% CI 1.31–1.61) of service-related TBI as compared to “Administration & Executives.”

Among enlisted service members, approximately 28% reported experiencing a service-related TBI. After adjusting for sex, branch of service, military status, number of before-

service TBI, and panel, the odds were attenuated for most of these MOCs, except for "Communications and Intelligence" which increased by 4%. After adjustment, the TBI odds increased and reached statistical significance for "Electrical/Mechanical Equipment Repairs." Among enlisted-specific MOCs, the odds of TBI were elevated for those serving in "Infantry, Gun Crews, Seamanship (OR: 1.79, 95% CI 1.58-2.02)," followed by "Electrical/Mechanical Equipment Repairers (OR: 1.23, 95% CI 1.09-1.38)," "Service & Supply Handlers (OR 1.21, 95% CI 1.08-1.37)," "Other Technical & Allied Specialists (OR 1.21, 95% CI 1.02 – 1.43)," "Health Care Specialists (OR 1.19, 95% CI 1.04-1.36)," and "Communications & Intelligence (OR: 1.16, 95% CI 1.02-1.31)," compared to "Functional Support & Administration" (Table IV).

Among officer service members, approximately 24% reported experiencing a service-related TBI. Among officer-specific MOCs, odds of TBI were highest for those serving as "Intelligence Officers" (OR 1.12, 95% CI 0.91-1.39), as compared to "Administrators" but not significantly. "Tactical Operations Officers," (OR: 0.80, 95% CI: 0.68-0.96) and "Health Care Officers," (OR: 0.61, 95% CI: 0.50-0.73) were the only MOCs with significantly different risk of TBI as compared to "Administrators" in unadjusted analysis. After adjustment, the protective odds against TBI for those serving as "Health Care Officers" was attenuated, but remained significant (OR: 0.65, 95% CI: 0.52-0.80), were no longer significant for "Tactical Operations Officers" (OR: 0.98, 95% CI: 0.80-1.19), and became significant for "Intelligence Officers" (OR: 1.27, 95% CI: 1.01-1.61) (Table IV).

DISCUSSION

This study examined the association between MOC and service-related TBI in a sample of Millennium Cohort Study participants. When MOCs were combined for enlisted and officer service members, all MOCs, apart from "Health Care," had significantly increased odds of reporting a service-related TBI as compared to those in "Administration & Executives" MOCs. The associations were attenuated when controlling for covariates but remained significant. Like previous studies, the highest odds of reporting a service-related TBI were in "Infantry/Tactical Operations" MOCs, which are often categorized as combat MOCs. The results presented also mirror those of the only other study to examine TBI risk by a greater stratification of MOCs.[7,26]

While this study compared combined MOCs like existing studies, it also considered the MOCs for enlisted and officer service members separately as this has not previously been described. Overall, enlisted service members were 72% more likely to report service-related TBI as compared to officers. The increased odds of TBI for enlisted service members became more evident in stratified analyses. Six out of eight MOCs compared to "Functional Support & Administration" were associated with significantly increased odds of TBI in enlisted service members, with odds 79% higher for "Infantry, Gun Crew, Seamanship" MOCs. For officer service members, only two out of seven MOCs compared to "Administrators" were associated with increased odds of service-related TBI. Interestingly, the "Intelligence Officers" MOCs had the highest odds, 27% of reporting a service-related TBI. This is contrary to the findings by Williams et al., which found "Communications/ Intelligence" MOCs to have lower incidence rates compared to combat-specific MOCs

(e.g., Infantry/Tactical Operations).[7] The discrepancy in findings may be due, in part, to the combining of MOCs for enlisted and officer service members. This fact is also demonstrated in our finding that "Health Care" MOCs were not at significantly increased risk overall, but when stratified by enlisted and officer, were at significantly increased odds of TBI for enlisted and decreased odds for officers. Further, in this analysis, "Tactical Operations Officers," an MOC, which would serve in the same unit as enlisted service members in "Infantry, Gun Crew, Seamanship" MOCs, did not have increased odds of reporting a service-related TBI. Still, the combined MOC "Infantry/Tactical Operations" and "Infantry, Gun Crew, Seamanship" had the highest odds of service-related TBI overall and within enlisted populations. While these service members of differing ranks serve within the same units, officers are more likely to be serving in a supervisory/managerial role upon their entry into service.[6] Enlisted service members may be exposed to more hazards early in their career prior to advancing into more supervisory positions within the MOCs. The combination of MOCs in research considering occupation may be masking a more pronounced problem within enlisted ranks. This masking becomes problematic when presenting results to stakeholders who may not consider the risk to be great enough to implement more targeted interventions.

MilCo panel, which served as a proxy measure for the time in service in this analysis, demonstrated that odds of reporting a service-related TBI decreased with each subsequent panel as compared to the final panel, panel 4. This is what was expected given panel 1 participants have the longest time in service and subsequently the greatest time at risk. It is also feasible that risk was higher in earlier panels due to the increased combat tempo of the armed services during the height of the wars in Iraq and Afghanistan, prior to the troop surge in 2007.

The finding of statistically significant decreased odds of TBI among Black and Asian/Pacific Islander service members as compared to White service members is similar to findings in other military TBI studies.[7,8,23] Published studies have adjusted for race in statistical modeling, but have not addressed the potential reason for higher rates of TBI among White service members. The present analysis found a larger proportion of White service members in MOCs with higher odds of TBI and lower proportion of White service members in MOCs at lower odds. For example, in this analysis White service members made up 21% of "Infantry/Tactical Operations" MOCs while Black service members made up 9%, and White service members made up 12% of "Administration & Executives" MOCs and Black service members made up 23%. Race categorizations did not allow for selection of more than one group for biracial participants and there are known variations in self-reported race and ethnicity categories when measured multiple times.[27] However, the MilCo data provided a single static category for each member of the cohort which could have led to misclassification the extension and direction of which is unknown. Further insight in the construction of race and ethnicity self-identification may be needed to fully comprehend the impact of race and ethnicity on TBI and its prevention and treatment.[28]

The most significant predictor of the relationship between MOC and TBI was reporting a TBI prior to military service. As compared to those service members with no history of TBI prior to entering military service, those who reported two or more TBI prior to service were

more than ten times likely to report experiencing a service-related TBI. This is consistent with previous studies which have cited TBI prior to military service as a risk factor for service-related TBI.[29] For example, Whitehead et al. found airmen with mTBI were at increased risk for future injury, stating the cause was likely due to individual differences in risk-taking behavior, utilization of health care for the injury, sports participation, and occupation.[23] This finding is also consistent with sports concussion research, which has found any history of TBI to be a risk factor for future TBI.[23,30-33]

While MilCo is collecting data for longitudinal analysis, the TBI questions were not added to the survey until the most recent wave. As a result, a limitation of this analysis is the cross-sectional design, which precludes us from inferring causal associations. Further, TBI and all variables used for analysis were self-reported which brings forth the potential limitation of recall bias, especially for those with TBI, which may affect memory. This bias is most likely to affect those who suffered from the most serious brain injuries, as the effect on their memory and ability to recall information would be more pronounced. However, the self-report limitation is also a strength of this analysis. Prior to implementation of the Post-Deployment Health Assessment and Post-Deployment Health Re-Assessment, which screen for TBI on return from deployment, many deployment-related injuries went unreported.[26] In fact, 94% of TBI identified in the 30 days following deployment were sustained during deployment.[26] Considering this screening is only done following deployment, this leaves a significant gap in reporting for those TBI which are not diagnosed or treated in non-deployment settings.

A further limitation includes the cross-sectional capture of self-reported MOC. It is possible for a service member to change their MOC during service. Therefore, misclassification of MOC at the time of TBI cannot be ruled out. A service member may change occupations, or reclassify, for a few reasons. Most commonly, reclassification occurs as the needs of a military service change and the demand for certain occupational specialties decreases. A great example of reclassification would be that occurring in the armed services at this time as women are integrated into combat MOCs which were previously limited to male service members only.[34] While reclassifications are possible, published rates on their commonality could not be located.

This study can be generalized to the military community at large as there were only minor differences between the study sample's demographics and those of the U.S. military. The sample was older, with the average age of the study sample around 37 years while the DoD reports an average age of 28.2 years.[35] Except for age, the remaining demographics of general U.S. military personnel were similar to those of the 2018 survey, with service members being mostly male (82%), White (71%), enlisted (82%), and serving in the Army (36%).[35]

A strength of this analysis is the breakdown of MOC associations with TBI stratified by enlisted and officer ranks which has been previously unreported. Given the significantly increased odds of service-related TBI reporting within enlisted ranks, further exploration into the location (deployed versus non-deployed) and mechanism (e.g., blast, training,

sports, etc.) for these injuries is needed. Understanding injury patterns within these military occupations is necessary to increase TBI identification, treatment, and foremost, prevention.

Finally, the economic burden of TBI in the USA has been estimated at $95 million in terms of direct medical costs and $14 billion dollars related to lost productivity.[36] These estimates of TBI illustrate the far-reaching consequences in terms of disability and long-term health. The standardization of these military occupations across services into DoD Occupational Codes also allows for standardization in data analysis and comparability to civilian job titles. As such, this research is translatable to some civilian occupations.

CONCLUSIONS

These results suggest increased reporting of service-related TBI across most MOCs in the military. The quantification of risk among enlisted MOCs suggests a need for further research into the causes of TBI. Determining specific occupational risk factors, such as mechanism and location of injury, will be necessary to further characterize these injuries. With TBI substantially increasing the risk of service-connected disability,[37] it is essential that researchers continue to explore inherent risk factors within military occupations. This includes an examination of the environment in which TBI occurs and the mechanisms implicated in increased injury.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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REFERENCES

1. Traumatic Brain Injury Center of Excellence: DOD TBI worldwide numbers. Defense Health Agency. Available at https://www.health.mil/Military-Health-Topics/Centers-of-Excellence/Traumatic-Brain-Injury-Center-of-Excellence/DOD-TBI-Worldwide-Numbers, updated November 10, 2021; accessed January 18, 2022.
2. Hoge CW, McGurk D, Thomas JL, Cox AL, Engel CC, Castro CA: Mild traumatic brain injury in U.S. Soldiers returning from Iraq. N Engl J Med 2008; 358(5): 453–63. [PubMed: 18234750]
3. Schneiderman AI, Braver ER, Kang HK: Understanding sequelae of injury mechanisms and mild traumatic brain injury incurred during the conflicts in Iraq and Afghanistan: persistent postconcussive symptoms and posttraumatic stress disorder. Am J Epidemiol 2008; 167(12): 1446–52. [PubMed: 18424429]

4. Terrio H, Brenner LA, Ivins BJ, et al. : Traumatic brain injury screening: preliminary findings in a US Army Brigade Combat Team. J Head Trauma Rehabil 2009; 24(1): 14–23. [PubMed: 19158592]
5. Terrio HP, Nelson LA, Betthauser LM, Harwood JE, Brenner LA: Postdeployment traumatic brain injury screening questions: sensitivity, specificity, and predictive values in returning soldiers. Rehabil Psychol 2011; 56(1): 26–31. [PubMed: 21401283]
6. Army US: Careers & jobs. Available at https://www.goarmy.com/careers-and-jobs/become-an-officer/army-officer-faqs.html, published 2015; accessed February 14, 2018.
7. Williams VF, Stahlman S, Hunt DJ, O'Donnell FL: Diagnoses of traumatic brain injury not clearly associated with deployment, active component, U.S. Armed Forces, 2001–2016. MSMR 2017; 24(3): 2–8.
8. Cameron KL, Marshall SW, Sturdivant RX, Lincoln AE: Trends in the incidence of physician-diagnosed mild traumatic brain injury among active duty U.S. military personnel between 1997 and 2007. J Neurotrauma 2012; 29(7): 1313–21. [PubMed: 22332633]
9. DOD Occupational Database (ODB): Department of Defense. 2018. accessed 02.
10. State Government of Michigan: DoD occupational codes. State Government of Michigan. Available at https://www.michigan.gov/documents/DoD_Occupational_Codes_154210_7.xls, published 2019; accessed February, 2019.
11. The Department of Defense: DoD Instruction 1312.01: Department of Defense occupational information collection and reporting [press release]. 2013. Available at https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/131201p.pdf; accessed September 12, 2019.
12. Lawson BD, Kass SJ, Dhillon KK, Milam LS, Cho TH, Rupert AH: Military occupations most affected by head/sensory injuries and the potential job impact of those injuries. Mil Med 2016; 181(8): 887–94. [PubMed: 27483529]
13. Gray GC, Chesbrough KB, Ryan MA, et al. : The millennium Cohort Study: a 21-year prospective cohort study of 140,000 military personnel. Mil Med 2002; 167(6): 483–8. [PubMed: 12099084]
14. Ryan MA, Smith TC, Smith B, et al. : Millennium Cohort: enrollment begins a 21-year contribution to understanding the impact of military service. J Clin Epidemiol 2007; 60(2): 181–91. [PubMed: 17208125]
15. Smith B, Smith TC, Gray GC, Ryan MA: Millennium Cohort Study Team: When epidemiology meets the internet: web-based surveys in the Millennium Cohort Study. Am J Epidemiol 2007; 166(11): 1345–54. [PubMed: 17728269]
16. Smith TC, Jacobson IG, Hooper TI, et al. : Health impact of US military service in a large population-based military cohort: findings of the Millennium Cohort Study, 2001–2008. BMC Public Health 2011; 11: 69. [PubMed: 21281496]
17. The Millennium Cohort Study: Millennium Cohort Study: fact sheet. In: Naval Health Research Center: DoD Center for Deployment Health Research. Naval Health Research Center; 2018:21.
18. The Millennium Cohort Study, Naval Health Research Center: About the study. The Department of Defense. published 2018, updated 2018. Available at https://www.millenniumcohort.org/about; accessed June 2018.
19. Belding JN, Englert R, Bonkowski J, Thomsen CJ: Occupational risk of low-level blast exposure and TBI-related medical diagnoses: a population-based epidemiological investigation (2005–2015). Int J Environ Res Public Health 2021; 18(24): 12925. [PubMed: 34948535]
20. Carr W, Kelley AL, Toolin CF, Weber NS: Association of MOS-based blast exposure with medical outcomes. Front Neurol 2020; (11): 619. [PubMed: 32849167]
21. Army Dot: Military occupational classification structure development and implementation. In: Vol Army Regulation 611–1: Department of Defense; 1997.
22. Army US: Military occupational specialty book. Available at https://usacac.army.mil/cac2/Retention/mos%20book.doc, Published 2008; accessed 2017.
23. Whitehead CR, Webb TS, Wells TS, Hunter KL: Airmen with mild traumatic brain injury (mTBI) at increased risk for subsequent mishaps. J Safety Res 2014; (48): 43–7. [PubMed: 24529090]
24. R Core Team, R Foundation for Statistical Computing: a language and environment for statistical computing. Vienna, Austria. 2019. Available at https://www.R-project.org/.
25. Hosmer DW, Lemeshow S, Sturdivant RX: Applied Logistic Regression. 3rd ed. Wiley; 2013:89–124.

26. Regasa LE, Agimi Y, Stout KC: Traumatic brain injury following military deployment: evaluation of diagnosis and cause of injury. J Head Trauma Rehabil 2019; 34(1): 21–9. [PubMed: 30045222]
27. Magana Lopez M, Bevans M, Wehrlen L, Yang L, Wallen GR: Discrepancies in race and ethnicity documentation: a potential barrier in identifying racial and ethnic disparities. J Racial Ethn Health Disparities 2016; 4(5): 812–18. [PubMed: 27631381]
28. Bierman AS, Lurie N, Collins KS, Eisenberg JM: Addressing racial and ethnic barriers to effective health care: the need for better data. Health Aff (Millwood) 2002; 21(3): 91–102. [PubMed: 12026007]
29. Lindquist LK, Love HC, Elbogen EB: Traumatic brain injury in Iraq and Afghanistan Veterans: new results from a national random sample study. J Neuropsychiatry Clin Neurosci 2017; 29(3): 254–9. [PubMed: 28121256]
30. Iverson GL, Gaetz M, Lovell MR, Collins MW: Cumulative effects of concussion in amateur athletes. Brain Inj 2004; 18(5): 433–43. [PubMed: 15195792]
31. Montenigro PH, Alosco ML, Martin BM, et al. : Cumulative head impact exposure predicts later-life depression, apathy, executive dysfunction, and cognitive impairment in former high school and college football players. J Neurotrauma 2017; 34(2): 328–40. [PubMed: 27029716]
32. Thornton AE, Cox DN, Whitfield K, Fouladi RT: Cumulative concussion exposure in rugby players: neurocognitive and symptomatic outcomes. J Clin Exp Neuropsychol 2008; 30(4): 398–409. [PubMed: 18938678]
33. Tsao JW, Stentz LA, Rouhanian M, et al. : Effect of concussion and blast exposure on symptoms after military deployment. Neurology 2017; 89(19): 2010–6. [PubMed: 29030450]
34. Department of the Army: Annual report on progress of the army in integrating women into military occupational specialties and units recently opened to women. Report to congress. Availabe at https://dacowits.defense.gov/Portals/48/Documents/General%20Documents/RFI%20Docs/Sept2019/USA%20RFI%205.pdf2019; accessed June 19, 2020.
35. Military OneSource: Demographics profile. 2018. Available at https://www.militaryonesource.mil/data-research-and-statistics/military-community-demographics/2018-demographics-profile2018; accessed August 18, 2020.
36. Kayani NA, Homan S, Yun S, Zhu BP: Health and economic burden of traumatic brain injury: Missouri, 2001–2005. Public Health Rep 2009; 124(4): 551–60. [PubMed: 19618792]
37. Eggleston B, Dismuke-Greer CE, Pogoda TK, et al. : A pred occupational risk of low-level blast exposure and TBI-related medical diagnoses iction model of military combat and training exposures on VA service-connected disability: a CENC study. Brain Inj 2019; 33(13–14): 1602–14. [PubMed: 31476880]

NOVELTY

This study has not been presented elsewhere.

TABLE I.

Sample Characteristics of 2014 Millennium Cohort Survey Respondents (*N* = 33,646)

Demographics	***N (%)***
Age, years (mean (SD))	37.3 (7.7)
Sex	
Female	9,570 (28.4)
Male	24,076 (71.6)
Race/Ethnicity	
White	24,578 (73.0)
Black	3,231 (9.6)
Hispanic	2,613 (7.8)
Asian/Pacific Islander	2,333 (6.9)
American Indian/Other	891 (2.6)
Rank	
Officer	9,954 (29.6)
Enlisted	23,692 (70.4)
Branch of Service	
Air Force	12,072 (35.9)
Army	13,859 (41.2)
Navy	5,063 (15.0)
Marine Corps	1,758 (5.2)
Coast Guard	894 (2.7)
Military Status	
Reserve/Guard	11,625 (34.6)
Active Duty	22,021 (65.4)
Total Before Service TBI	
None	26,294 (78.1)
One	3,813 (11.3)
Two or More	3,539 (10.5)
Millennium Cohort Panel	
Panel 1	9,208 (27.4)
Panel 2	4,163 (12.4)
Panel 3	7,253 (21.6)
Panel 4	13,022 (38.7)
Military Occupational Category	
Administration & Executives	4,516 (13.4)
Infantry/Tactical Operations	6,350 (18.9)
Electronic Repair & Engineering	6,719 (20.0)
Communications & Intelligence	4,165 (12.4)
Health Care	4,503 (13.4)
Technical & Professional	2,142 (6.4)
Craftworkers & Supply	5,251 (15.6)

SD = Standard Deviation.

TABLE II.

Distribution of Combined Military Occupational Categories (MOC) and Their Association with Service-related Traumatic Brain Injury (TBI) Status in Millennium Cohort Survey Respondents, 2014 (N = 33,464)

MOC, %	Overall (n = 33,646)	No TBI (n = 24,529)	Yes TBI (n = 9,117)	Unadjusted OR (95% CI)
Administration & Executives	4,516	75.7	24.3	1.00 (ref)
Infantry/Tactical Operations	6,350	67.7	32.3	**1.49 (1.37, 1.62)**
Electronic Repair & Engineering	6,719	74.6	25.4	1.06 (0.97, 1.16)
Communications & Intelligence	4,165	72.3	27.7	**1.19 (1.08, 1.31)**
Health Care	4,503	76.0	24.0	0.99 (0.90, 1.09)
Technical & Professional	2,142	73.4	26.6	**1.13 (1.01, 1.27)**
Craftworkers & Supply	5,251	72.2	27.8	**1.20 (1.10, 1.32)**

P-values <.05 are indicated in bold; OR = Odds Ratio.

TABLE III.

Multivariable Logistic Regression Model of Service-related Traumatic Brain Injury in a Sample of 2014 Millennium Cohort Participants (N = 33,646)

Predictor	Odds Ratio (95% CI)
Sex	
Female	1.00 (Ref)
Male	1.12 (1.05, 1.20)[c]
Race/Ethnicity	
White	1.00 (Ref)
Black	0.76 (0.69, 0.84)[c]
Hispanic	0.95 (0.86, 1.05)
Asian/Pacific Islander	0.82 (0.73, 0.92)[c]
American Indian/Other	1.14 (0.96, 1.35)
Rank	
Officer	1.00 (Ref)
Enlisted	1.72 (1.62, 1.85)[c]
Branch of Service	
Air Force	1.00 (Ref)
Army	2.85 (2.67, 3.05)[c]
Navy	1.27 (1.16, 1.39)[c]
Marine Corps	2.23 (2.03, 2.60)[c]
Coast Guard	1.09 (0.90, 1.31)
Military Status	
Reserve/Guard	1.00 (Ref)
Active Duty	1.40 (1.31, 1.48)[c]
Total Before-Service TBI	
None	1.00 (Ref)
One	5.14 (4.77, 5.53)[c]
Two or More	10.55 (9.71, 11.45)[c]
Millennium Cohort Panel	
Panel 4	1.00 (Ref)
Panel 1	1.72 (1.60, 1.84)[c]
Panel 2	1.46 (1.33, 1.59)[c]
Panel 3	1.23 (1.14, 1.33)[c]
Military Occupational Category	
Administration & Executives	1.00 (Ref)
Infantry/Tactical Operations	1.45 (1.31, 1.61)[c]
Electronic Repair & Engineering	1.19 (1.08, 1.32)[c]
Communications & Intelligence	1.19 (1.07, 1.33)[b]

Predictor	Odds Ratio (95% CI)
Health Care	1.01 (0.91, 1.13)
Technical & Professional	1.16 (1.02, 1.33)[a]
Craftworkers & Supply	1.18 (1.06, 1.31)[b]

[a] $P < .05$

[b] P < .01

[c] P < .001.

CI = Confidence interval.

TABLE IV.

Distribution of Enlisted and Officer Military Occupational Categories (MOC) by Service-related Traumatic Brain Injury (TBI) Status, Millennium Cohort 2014 Survey Respondents

Enlisted MOC *n* (%)	**Overall (*n* = 23,692)**	**No TBI (*n* = 16,994)**	**Yes TBI (*n* = 6,698)**	**Unadjusted OR (95% CI)**	**Adjusted OR (95% CI)[a]**
Functional Support & Administration	3,475	2,655 (76.4)	820 (23.6)	1.00 (ref)	1.00 (ref)
Infantry, Gun Crews, Seamanship	3,214	1,892 (58.9)	1,322 (41.1)	**2.26 (2.04, 2.51)**	**1.79 (1.58, 2.02)**
Electronic Equipment Repairers	1,061	806 (76.0)	255 (24.0)	1.02 (0.87, 1.20)	0.98 (0.81, 1.17)
Communications & Intelligence	3,319	2,418 (72.9)	901 (27.1)	**1.12 (1.08, 1.35)**	**1.16 (1.02, 1.31)**
Health Care Specialists	2,716	1,965 (72.3)	751 (27.7)	**1.24 (1.10, 1.39)**	**1.19 (1.04, 1.36)**
Other Technical & Allied Specialists	1,240	895 (72.2)	345 (27.8)	**1.25 (1.08, 1.45)**	**1.21 (1.02, 1.43)**
Electrical/Mech. Equipment Repairers	4,398	3,272 (74.4)	1,126 (25.6)	1.11 (1.00, 1.24)	**1.23 (1.09, 1.38)**
Craftworkers	775	579 (74.7)	196 (25.3)	1.10 (0.92, 1.31)	1.21 (0.99, 1.48)
Service & Supply Handlers	3,494	2,512 (71.9)	982 (28.1)	**1.27 (1.14, 1.41)**	**1.21 (1.08, 1.37)**
Officer MOC, *n* (%)	Overall (*n* = 9,954)	No TBI (*n* = 7,535)	Yes TBI (*n* = 2,419)		
Administrators	868	631 (72.7)	237 (23.7)	1.00 (ref)	1.00 (ref)
General Officers & Executives	173	134 (77.5)	39 (22.5)	0.77 (0.52, 1.13)	0.78 (0.50, 1.20)
Tactical Operations Officers	3,136	2,408 (76.8)	728 (23.2)	**0.80 (0.68, 0.96)**	0.98 (0.80, 1.19)
Intelligence Officers	846	595 (70.3)	251 (29.7)	1.12 (0.91, 1.39)	**1.27 (1.01, 1.61)**
Engineering & Maintenance	1,260	934 (74.1)	326 (25.9)	0.93 (0.76, 1.13)	1.15 (0.92, 1.43)
Scientists & Professionals	902	677 (75.1)	225 (24.9)	0.88 (0.72, 1.09)	0.94 (0.74, 1.20)
Health Care Officers	1,787	1,456 (81.5)	331 (18.5)	**0.61 (0.50, 0.73)**	**0.65 (0.52, 0.80)**
Supply, Procurement, Allied Officers	982	700 (71.3)	282 (28.7)	1.07 (0.88, 1.32)	1.07 (0.85, 1.34)

P-values <.05 are indicated in bold.

[a]Adjusted for sex, branch of service, military status, number of before service TBI, and Panel.