HHS Public Access

Author manuscript

N C Med J. Author manuscript; available in PMC 2023 May 01.

Published in final edited form as:

N C Med J. 2022 ; 83(3): 206–213. doi:10.18043/ncm.83.3.206.

Examination of Behaviors and Health Indicators for Individuals with a Lifetime History of Traumatic Brain Injury with Loss of Consciousness: 2018 BRFSS North Carolina

Dana Waltzman [behavioral scientist],
Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, Atlanta, Georgia.

Kelly Sarmiento [health communication specialist],
Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, Atlanta, Georgia.

Jill Daugherty [epidemiologist],
Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, Atlanta, Georgia.

Scott Proescholdbell [epidemiologist]
North Carolina Department of Health and Human Services, Division of Public Health, Raleigh, North Carolina.

Abstract

BACKGROUND—Evidence suggests that those who have sustained a traumatic brain injury (TBI) are at increased risk of adverse behaviors and health indicators, such as certain chronic physical and mental health conditions. However, little is known about the prevalence of these behaviors and health indicators among these individuals, information that could help decrease their risk of developing such conditions.

METHODS—Data (N = 4733) from the 2018 North Carolina Behavioral Risk Factor Surveillance System (BRFSS) were analyzed to determine the prevalence of behaviors and health indicators among individuals who report having a lifetime history of TBI with loss of consciousness (LOC).

RESULTS—North Carolinians who report a lifetime history of TBI with LOC were at increased risk of reporting a range of 3 negative health behaviors: less than always seatbelt use (adjusted odds ratio [AOR] = 1.7; 95% confidence interval [CI] = 1.2–2.4), HIV risk behaviors (AOR = 1.7; 95% CI = 1.1–2.6), and reporting less than 7 hours of sleep (AOR = 1.5; 95% CI = 1.2–1.8); more difficulty obtaining health care (not seeing a doctor due to health care cost in the past 12 months [AOR = 1.3; 95% CI = 1.0–1.8]; not getting a routine medical check-up in the past 12 months

Address correspondence to Dana Waltzman, National Center for Injury Prevention and Control Centers for Disease Control and Prevention, 4770 Buford Hwy, S106-9, Atlanta, GA 30341 (DWaltzman@cdc.gov).

Disclosure of interests: All authors report no relevant disclosures.

SUPPLEMENTAL TABLE 1 Select Health Behaviors by Demographic Characteristics and Lifetime History of Traumatic Brain Injury with Loss of Consciousness, North Carolina Behavioral Risk Factor Surveillance System, 2018
This appendix is available in its entirety in the online edition of the NCMJ.

[AOR = 1.5; 95% CI = 1.2–2.0]); worse self-reported health (fair or poor general health [AOR = 1.8; 95% CI = 1.4–2.3]); and reporting fair or poor mental health (AOR = 2.1; 95% CI = 1.6–2.8) compared with individuals who did not report a history of TBI.

LIMITATIONS—There are several limitations to the study, such as the sample being biased toward more severe brain injuries. Additionally, because the data in the BRFSS are retrospective and cross-sectional, it is not possible to determine temporality and causality between TBI history and the behaviors and health indicators examined.

CONCLUSION—Despite these limitations, this paper is one of the first to directly examine the association between history of TBI with LOC and a range of current behaviors and health care utilization. Assessing positive and negative behaviors and health indicators can help identify and tailor evidence-based interventions for those who have a history of TBI.

Previous research demonstrates that individuals living with traumatic brain injury (TBI) are at increased risk for developing chronic health conditions such as depression [1, 2], diabetes [3], and heart disease [3], and having overall poor health [4]. Those with a moderate/severe TBI have an increased risk of dying within 5 years of the injury [5]. Sustaining a TBI has also been linked to moderate-to-severe problem gambling [6], risky sexual behavior [7], substance use disorders [8, 9], increased risk for sustaining an unintentional injury (such as a motor vehicle crash) [10], and suicidal thoughts and behaviors [2].

Physical activity, proper sleep hygiene, community-based support services, routine medical check-ups, and wearing seatbelts and taking other safety precautions can contribute to good physical and mental health, including for individuals with a history of TBI [4, 11, 12]. However, less is known about whether people who have sustained a TBI engage in protective health behaviors. The goal of this paper is to examine and present the prevalence of selected positive and negative behaviors and health indicators among individuals who report having a lifetime history of TBI with self-reported loss of consciousness (LOC). It is hypothesized that those with a history of TBI with LOC were more likely to engage in risk-taking behaviors.

Methods

Study Population

The Behavioral Risk Factor Surveillance System (BRFSS) is an annual, nationally representative telephone survey of non-institutionalized US adults, aged 18 and older that collects information pertaining to health-related conditions and behaviors [13]. BRFSS collects data from all 50 states, the District of Columbia, and 3 US territories. It is the largest continuously conducted health survey system in the world and is a powerful tool for targeting and building health promotion activities (https://www.cdc.gov/brfss/about/index.htm). The BRFSS survey consists of 3 parts: the core component, optional modules, and state-added questions (https://www.cdc.gov/brfss/questionnaires/index.htm). The BRFSS employs a complex sampling design [14]; it uses a disproportionate stratified sample design for respondents who complete the survey by landline and a random sample design for those who complete the survey by cell phone. The BRFSS also uses iterative proportional fitting to weight the data. BRFSS data are deidentified and considered exempt

from human subjects review by CDC's Institutional Review Board. Analyses for this study only used data from North Carolina BRFSS respondents as North Carolina is one of the few states that incorporated a module that asked TBI-related questions. Data from the other states that included a TBI module in 2018 could not be combined due to differences in the TBI-related questions. In 2018, 4733 adults in North Carolina completed the core sections of the BRFSS using a landline or cell phone (response rate of 43.5%).

Traumatic Brain Injury Module

Similar to the Ohio BRFSS TBI state module [15], the North Carolina BRFSS TBI module is a modified version of the Ohio BRFSS TBI module and focused on questions on lifetime history of TBI with LOC only. TBI is a heterogeneous disorder with various symptoms. LOC is one such symptom with a prevalence between 5.7% and 12% [2, 16, 17]. LOC is more accurately self-reported with certainty than other symptoms and may signify a disruption of brain function [18]. After completing the core sections of the BRFSS, the TBI module was administered. For the TBI module, all respondents received the following prompt:

> For these next questions, please think about injuries you have had during your entire lifetime, especially those that affected your head or neck. It might help to remember times you went to the hospital or emergency room. Think about injuries you may have received from a car or motorcycle wreck, bicycle crash, being hit by something, falling down, being hit by someone, playing sports, or an injury during military service.

This prompt was followed by the questions: "Thinking about any injuries you have had in your lifetime, were you ever knocked out or did you lose consciousness?" and "How old were you the first time you were knocked out or lost consciousness?" Responses to the first question were dichotomized as yes/no. The number of years since a respondent's first TBI with LOC was calculated by subtracting age of first TBI from the age of the respondent at the time of the survey.

Behaviors and Health Indicators

The slate of behaviors and health indicators examined in this paper were chosen due to previous research, which demonstrated that having a past history of TBI is associated with risk-taking [2, 6–10], poor overall health status [4], and difficulty obtaining adequate health care [19]. In order to examine the association of risk-taking behaviors and TBI, we selected seatbelt usage, HIV risk behaviors, and problem/pathological gambling. To examine difficulty obtaining health care, we selected the variables that assessed not seeing a doctor due to health care cost, recent routine checkup, and health care coverage. To examine the association between TBI history and overall health status, we selected self-rated general health and mental health and sleep. The behaviors, health indicators, and dichotomized responses are displayed in Table 1.

Statistical Analysis

Descriptive statistics were calculated to describe the demographic characteristics (sex, age, race/ethnicity, veteran status, marital status, educational attainment, and employment status)

of North Carolina adults (Table 2). These statistics were limited to those who answered "yes" or "no" to the lifetime TBI with LOC question (N = 3570). To account for the complex design of the BRFSS, frequencies and weighted percentages were estimated and compared across subgroups using χ^2 tests, along with corresponding 95% confidence intervals (CI). The bivariate statistics were also limited to those who answered "yes" or "no" to the lifetime TBI with LOC question and the respective health behavior or outcome. To determine the association between TBI with behaviors and health indicators (i.e., seatbelt use, HIV risk behaviors, gambling, health care coverage, not seeing a doctor due to health care cost, recent routine check-up, general health, mental health, and sleep), separate multivariable binomial logistic regression was used to create models for each independent variable (i.e., lifetime history of TBI with LOC, number of years since first TBI with LOC), using the "no outcome" or "worse outcome" conditions as the reference group and adjusting for the demographic characteristics that were significant in the χ^2 tests. Separate analyses were conducted for each of the behavior or health indicator variables. Additionally, if the primary outcome of interest (lifetime TBI with LOC) was not significant in the multivariable binomial logistic regression, then the secondary outcome of number of years since first TBI with LOC was not conducted. All analyses were performed in SAS 9.4 (SAS Institute, Cary, NC).

Results

A quarter of the respondents (24.8%) in North Carolina in 2018 had a self-reported history of TBI with LOC (Table 2). Among these respondents, the median age in which it was first experienced was 16.1 years, with most respondents experiencing a mild TBI (85.2%). Among all respondents, approximately: 7.7% reported "less than always" using a seatbelt, 6.1% reported at least 1 risk behavior for HIV, 5.0% reported problem/pathological gambling, 14.6% reported not having current health care coverage, 16.3% reported not seeing a doctor due to health care cost in the past 12 months, 19.7% reported not getting a routine medical check-up in the past year, 20.6% reported fair or poor health, 12.6% reported not having good mental health, and 34.5% reported sleeping less than 7 hours a night on average.

Risk-Taking Health Behaviors

After adjustment for demographic factors that were significantly associated with each behavior or health indicator (Supplementary Table 1), lifetime history of TBI with LOC was associated with increased odds of reporting less-than-always seatbelt use (adjusted odds ratio [AOR] = 1.7; 95% confidence interval [CI] = 1.2–2.4) and HIV risk behaviors (AOR = 1.7; 95% CI = 1.1–2.6), (Table 3). The bivariate association between lifetime history of TBI with LOC and problem/pathological gambling was not significant; thus, no multivariable modeling was conducted for this variable.

After adjustment for significant demographic factors (Supplementary Table 1), number of years since first TBI with LOC was not associated with reported seatbelt use or HIV risk behaviors in the bivariate analyses (Table 3). Additionally, since there was no association between the primary outcome variable (lifetime history of TBI with LOC) and problem/

pathological gambling, the multivariable analysis for number of years since first TBI with LOC and problem/pathological gambling was not conducted.

Difficulty Obtaining Health Care

After adjustment for significant demographic factors (Supplementary Table 1), lifetime history of TBI with LOC was associated with increased odds of reporting not seeing a doctor due to health care cost in the past 12 months (AOR = 1.3; 95% CI = 1.0–1.8) and not getting a routine medical check-up in the past 12 months (AOR = 1.5; 95% CI = 1.2–2.0) (Table 3). The bivariate association between lifetime history of TBI with LOC and health care coverage was not significant; thus, no multivariate modeling was conducted.

After adjustment for significant demographic factors (Supplementary Table 1), number of years since first TBI with LOC was not associated with not seeing a doctor due to health care cost in the past 12 months or getting a routine checkup in the past 12 months (Table 3).

Health Status

After adjustment for significant demographic factors (Supplementary Table 1), lifetime history of TBI with LOC was associated with increased odds of reporting fair or poor general health (AOR = 1.8; 95% CI = 1.4–2.3), reporting fair or poor mental health (AOR = 2.1; 95% CI = 1.6–2.8), and reporting < 7 hours of sleep (AOR = 1.5; 95% CI = 1.2–1.8) (Table 3).

The bivariate association between number of years since first TBI with LOC and general health or sleep was not significant; thus, no multivariable modeling was conducted. After adjustment for significant demographic factors (Supplementary Table 1), number of years since first TBI with LOC was not associated with mental health (Table 3).

Discussion

Our study indicates that individuals in North Carolina who reported a lifetime history of TBI with LOC were at increased risk of reporting a range of adverse behaviors and health indicators (e.g., negative health behaviors, more difficulty obtaining health care, and worse self-reported health than individuals who do not report a history of TBI). For example, findings suggest that individuals with a lifetime history of TBI with LOC had increased odds of reporting 3 risk behaviors: less than always using a seatbelt, HIV risk behaviors, and fewer than 7 hours of sleep, though the prevalence of less than always using a seatbelt and HIV risk behaviors is still very low among respondents in North Carolina. No previous studies have specifically examined the relationship between seatbelt usage after TBI or HIV risk behaviors and TBI; however, 1 study did find a high prevalence of previous head trauma (74%) among a sample of 173 individuals living with HIV [20]. Development of interventions that address impulsivity and risk-taking behaviors following a TBI, such as those that might put an individual at risk for HIV, is an area that deserves further study [21]. The relationship between sleep and TBI, on the other hand, is well-researched [22–27]. A 2012 meta-analysis reported that sleep disturbances are present in 50% of individuals who have sustained a TBI and that these individuals were 2–4 times more likely to experience problems with sleep maintenance, early awakenings, and excessive sleepiness (e.g., falling

asleep during the day or sleeping longer at night) than people who did not have a history of TBI [23]. This relationship between TBI and poor sleep outcomes is particularly striking given the critical role that good sleep plays in recovery from TBI [28]. Future research may examine the extent to which people living with TBI are provided with guidance from health care providers on sleep hygiene following a TBI, as well as whether they receive referrals to specialists when symptoms persistent.

Lifetime history of TBI with LOC was also associated with increased odds of reporting not seeing a doctor due to health care cost in the past 12 months and not getting a routine medical check-up in the past 12 months. Previous research has shown that failure to obtain care after a suspected concussion can have lasting health implications, prolong recovery, and increase the possibility that a person will sustain a second concussion before symptoms resolve from the first one [29–31]. However, our study did not allow us to determine the relationship between the timing of the TBI and health care usage soon after the injury. Generally, preventive care services (such as routine health screenings and immunizations) help to reduce death and disability [32]. Consequently, lack of access to health care and other inequalities (e.g., lower hospital admission rates based on a patient's insurance status, race, and sex) may partially explain poor patient outcomes [19]. Future longitudinal studies may explore these factors as mediators to better understand the impacts in order to reduce some of the harmful long-term effects of sustaining a TBI. Moreover, evaluation of interventions to overcome these barriers may be beneficial.

Finally, our study also demonstrated that lifetime history of TBI with LOC was associated with increased odds of reporting fair or poor general health and reporting fair or poor mental health. In a sample of 1129 male service members with a history of blast-related mild TBI, Heltemes and colleagues reported that service members with mild TBI were 5 times more likely to report a major negative change in health compared to members with other mild injuries [33]. Additionally, there is a robust literature demonstrating the relationship between post-TBI mental illness and personality changes [34–37]. For example, secondary attention deficit hyperactivity disorder (S-ADHD), aggression, and personality changes was more common with increasing TBI severity [35, 38]. Future research may explore the effectiveness of rehabilitation services for veterans with TBI complicated by psychological sequelae [39]. Health care providers can consider screening for these adverse health outcomes in individuals with TBI and provide referrals for evidence-based services as needed.

There are several limitations to this study. First, the TBI questions are biased toward more severe brain injuries due to the requirement about needing to have experienced LOC as a result of the TBI. Second, because the data in the BRFSS are retrospective and cross-sectional, it is not possible to determine temporality and causality between TBI history and the onset of the reported health behaviors, health care usage, or self-reported health status. There may also have been recall bias for respondents to not accurately remember details of an event (especially for recall of lifetime history of TBI). However, each of the behaviors and health indicators examined were current or within the past 12 months, so it is likely that in most cases the TBI preceded the behavior or health indicator. Third, these data were collected among respondents in North Carolina only and may not be generalizable to

other US states. For example, our study found a prevalence of TBI with LOC of 24.8%, but other studies report a prevalence between 5.7% and 12% [2, 16, 17]. According to the US Department of Veterans Affairs, North Carolina ranks 8th among US states with the highest population of veterans [40], a population that is more likely to report a history of TBI with LOC, and this may contribute to the higher prevalence of TBI seen in this study. It is important to collect data on the TBI experience among residents of other states to see how it varies. Fourth, there was a high percentage of missing data for the lifetime TBI with LOC question (e.g., 22% of respondents did not answer the question, n = 1094). This was due to partial completion of the survey (i.e., respondents who ended the interview before the TBI optional module) or respondents who moved to North Carolina but kept their old cell phone number and thus were only asked questions from the core BRFSS. Further, respondents who did not answer this question compared to those who did were different on all demographic characteristics, as well as health care cost and general health. For example, respondents who answered the self-reported lifetime TBI with LOC question were more likely to be female, older, less likely to have a college education or higher, had not seen a doctor in the past 12 months due to health care cost, and had worse general health compared to respondents who had missing data. Fifth, the sleep variable was defined as a binary variable (less than 7 hours of sleep and 7 hours or more of sleep). Hypersomnia and excessive sleep are often problematic in individuals who sustain a TBI [23]. However, only 3.2% of respondents in our data endorsed more than 9e hours of sleep, and due to a lack of stability of the data caused by a low N, an analysis with tertiary levels was not possible. Future studies may want to examine this relationship. Sixth, it may be the case that those at risk for TBI are more impulsive or risky in general and there may not be a direct relationship between TBI and adverse health outcomes. Seventh, this study did not analyze TBI severity or number of TBIs. Though descriptive statistics were presented for TBI severity, there was too small a sample size for further analysis. Future studies may want to examine these variables as well.

Despite these limitations, this paper is one of the first to directly examine the association between history of TBI with LOC and a range of current behaviors and health care utilization. Further, it adds to the established literature showing a strong correlation between history of TBI with LOC and self-reported poor physical and mental health. Additionally, these findings may help inform screening and referral strategies for health care providers for the care of patients with a history of TBI to promote a healthy lifestyle.

Conclusion

Taken together, the results of this analysis demonstrate that individuals who have sustained a TBI with LOC in their lifetime had increased odds of reporting certain negative health behaviors, less health care usage, and poor physical and mental self-rated health than individuals who have not sustained a TBI with LOC. Targeted TBI prevention efforts of modifiable risk and protective behaviors (such as seatbelt use), as well as the adaptation of evidence-based programs, are needed in order to reduce adverse health outcomes in patients with TBI. Additionally, health care providers can consider screening patients with a lifetime history of TBI with LOC for mental health and sleep problems and provide referrals for evidence-based services as needed.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The findings and conclusions in this manuscript are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

References

1. Singh R, Mason S, Lecky F, Dawson J. Prevalence of depression after TBI in a prospective cohort: the SHEFBIT study. Brain Inj. 2018;32(1):84–90. doi: 10.1080/02699052.2017.1376756 [PubMed: 29190146]
2. Anstey KJ, Butterworth P, Jorm AF, Christensen H, Rodgers B, Windsor TD. A population survey found an association between self-reports of traumatic brain injury and increased psychiatric symptoms. J Clin Epidemiol. 2004;57(11):1202–9. doi :10.1016/j.jclinepi.2003.11.011 [PubMed: 15567638]
3. Selassie AW, Cao Y, Church EC, Saunders LL, Krause J. Accelerated death rate in population-based cohort of persons with traumatic brain injury. J Head Trauma Rehabil. 2014;29(3):E8–E19. doi: 10.1097/HTR.0b013e3182976ad3 [PubMed: 23835874]
4. Driver S, Juengst S, Reynolds M, et al. Healthy lifestyle after traumatic brain injury: a brief narrative. Brain Inj. 2019;33(10):1299–1307. doi: 10.1080/02699052.2019.1641623 [PubMed: 31296066]
5. Corrigan JD, Cuthbert JP, Harrison-Felix C, et al. US population estimates of health and social outcomes 5 years after rehabilitation for traumatic brain injury. J Head Trauma Rehabil. 2014;29(6):E1–9. doi: 10.1097/htr.0000000000000020
6. Turner NE, McDonald AJ, Ialomiteanu AR, et al. Moderate to severe gambling problems and traumatic brain injury: A population-based study. Psychiatry Res. 2019;272:692–697. doi: 10.1016/j.psychres.2018.12.170 [PubMed: 30832188]
7. Moreno JA, McKerral M. Relationships between risky sexual behaviour, dysexecutive problems, and mental health in the years following interdisciplinary TBI rehabilitation. Neuropsychol Rehabil. 2018;28(1):34–56. doi: 10.1080/09602011.2015.1136222 [PubMed: 26872445]
8. Kennedy E, Cohen M, Munafo M. Childhood traumatic brain injury and the associations with risk behavior in adolescence and young adulthood: a systematic review. J Head Trauma Rehabil. 2017;32(6):425–432. doi: 10.1097/htr.0000000000000289 [PubMed: 28092286]
9. Allen S, Stewart SH, Cusimano M, Asbridge M. Examining the relationship between traumatic brain injury and substance use outcomes in the Canadian population. Subst Use Misuse. 2016;51(12):1577–1586. doi: 10.1080/10826084.2016.1188955 [PubMed: 27484302]
10. Kolakowsky-Hayner SA, Bellon K, Yang Y. Unintentional injuries after TBI: potential risk factors, impacts, and prevention. NeuroRehabilitation. 2016;39(3):363–370. doi: 10.3233/nre-161368 [PubMed: 27497469]
11. Brown AW, Moessner AM, Mandrekar J, Diehl NN, Leibson CL, Malec JF. A survey of very-long-term outcomes after traumatic brain injury among members of a population-based incident cohort. J Neurotrauma. 2011;28(2):167–176. doi: 10.1089/neu.2010.1400 [PubMed: 21121813]
12. National Highway Traffic Safety Administration. Lives Saved in 2017 by Restraint Use and Minimum-Drinking-Age Laws. Published March 2019. Accessed February 15, 2022. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812683
13. North Carolina State Center for Health Statistics Department of Public Health. North Carolina 2018 Questionnaire: Behavioral Risk Factor Surveillance System. Published 2018. Accessed February 15, 2022. https://schs.dph.ncdhhs.gov/schs/brfss/pdf/BRFSSQ18.pdf
14. Centers for Disease Control and Prevention and US Department of Health and Human Services. The Behavioral Risk Factor Surveillance System: Comparability of Data BRFSS 2018. Revised August 2019. https://www.cdc.gov/brfss/annual_data/2018/pdf/compare-2018-508.pdf

15. Bogner J, Corrigan JD, Yi H, et al. Lifetime history of traumatic brain injury and behavioral health problems in a population-based sample. J Head Trauma Rehabil. 2020;35(1):E43–E50. doi: 10.1097/htr.0000000000000488 [PubMed: 31033748]
16. Frost RB, Farrer TJ, Primosch M, Hedges DW. Prevalence of traumatic brain injury in the general adult population: a meta-analysis. Neuroepidemiology. 2013;40(3):154–159. doi: 10.1159/000343275 [PubMed: 23257914]
17. Silver JM, Kramer R, Greenwald S, Weissman M. The association between head injuries and psychiatric disorders: findings from the New Haven NIMH Epidemiologic Catchment Area Study. Brain Inj. 2001;15(11):935–45. doi: 10.1080/02699050110065295 [PubMed: 11689092]
18. Ruff RM, Iverson GL, Barth JT, Bush SS, Broshek DK, NAN Policy and Planning Committee. Recommendations for diagnosing a mild traumatic brain injury: a National Academy of Neuropsychology education paper. Arch Clin Neuropsychol. 2009;24:3–10. doi: 10.1093/arclin/acp006 [PubMed: 19395352]
19. Selassie AW, Pickelsimer EE, Frazier L Jr, Ferguson PL. The effect of insurance status, race, and gender on ED disposition of persons with traumatic brain injury. Am J Emerg Med. 2004;22(6):465–473. doi: 10.1016/j.ajem.2004.07.024 [PubMed: 15520941]
20. Jaffe MP, O'Neill J, Vandergoot D, Gordon WA, Small B. The unveiling of traumatic brain injury in an HIV/AIDS population. Brain injury. 2000;14(1):35–44. doi: 10.1080/026990500120916 [PubMed: 10670660]
21. James LM, Strom TQ, Leskela J. Risk-taking behaviors and impulsivity among veterans with and without PTSD and mild TBI. Mil Med. 2014;179(4):357–363. doi: 10.7205/milmed-d-13-00241 [PubMed: 24690958]
22. Viola-Saltzman M, Watson NF. Traumatic brain injury and sleep disorders. Neurol Clin. 2012;30(4):1299–1312. doi: 10.1016/j.ncl.2012.08.008 [PubMed: 23099139]
23. Mathias J, Alvaro P. Prevalence of sleep disturbances, disorders, and problems following traumatic brain injury: a meta-analysis. Sleep Med. 2012;13(7):898–905. doi: 10.1016/j.sleep.2012.04.006 [PubMed: 22705246]
24. Kempf J, Werth E, Kaiser PR, Bassetti CL, Baumann CR. Sleep–wake disturbances 3 years after traumatic brain injury. J Neurol Neurosurg Psychiatry. 2010;81(12):1402–1405. doi: 10.1136/jnnp.2009.201913 [PubMed: 20884672]
25. Ouellet M-C, Beaulieu-Bonneau S, Morin CM. Sleep-wake disturbances after traumatic brain injury. Lancet Neurol. 2015;14(7):746–757. doi: 10.1016/S1474-4422(15)00068-X [PubMed: 26067127]
26. Castriotta RJ, Murthy JN. Sleep disorders in patients with traumatic brain injury. CNS drugs. 2011;25(3):175–185. doi: 10.2165/11584870-000000000-00000 [PubMed: 21062105]
27. Viola-Saltzman M, Musleh C. Traumatic brain injury-induced sleep disorders. Neuropsychiatr Dis Treat. 2016;12: 339–348. doi: 10.2147/NDT.S69105 [PubMed: 26929626]
28. Theadom A, Cropley M, Parmar P, et al. Sleep difficulties one year following mild traumatic brain injury in a population-based study. Sleep Med. 2015;16(8):926–932. doi: 10.1016/j.sleep.2015.04.013 [PubMed: 26138280]
29. O'Connor K, Allred D, Cameron K, et al. History of diagnosed and undiagnosed concussions at baseline had differential impact on neurocognitive performance and symptom scores. J Neurol Sci. 2017;381:758. doi: 10.1016/j.jns.2017.08.2139
30. Meehan WP III, Zhang J, Mannix R, Whalen MJ. Increasing recovery time between injuries improves cognitive outcome after repetitive mild concussive brain injuries in mice. Neurosurgery. 2012;71(4):885–892. doi: 10.1227/NEU.0b013e318265a439 [PubMed: 22743360]
31. Byard RW, Vink R. The second impact syndrome. Forensic Sci Med Pathol. 2009;5(1):36–38. doi: 10.1007/s12024-008-9063-7 [PubMed: 19148785]
32. US Department of Health and Human Services. Clinical Preventive Services. USDHHS website. Accessed December 17, 2019. https://www.healthypeople.gov/2020/leading-health-indicators/2020-lhi-topics/Clinical-Preventive-Services
33. Heltemes KJ, Holbrook TL, MacGregor AJ, Galarneau MR. Blast-related mild traumatic brain injury is associated with a decline in self-rated health amongst US military personnel. Injury. 2012;43(12):1990–1995. doi: 10.1016/j.injury.2011.07.021 [PubMed: 21855064]

34. Ilie G, Mann RE, Boak A, et al. Suicidality, bullying and other conduct and mental health correlates of traumatic brain injury in adolescents. PloS one. 2014;9(4):e94936. doi: 10.1371/journal.pone.0094936 [PubMed: 24736613]

35. Schachar RJ, Park LS, Dennis M. Mental health implications of traumatic brain injury (TBI) in children and youth. J Can Acad Child Adolesc Psychiatry. 2015;24(2):100–108. [PubMed: 26379721]

36. Andelic N, Sigurdardottir S, Schanke AK, Sandvik L, Sveen U, Roe C. Disability, physical health and mental health 1 year after traumatic brain injury. Disabil Rehabil. 2010;32(13):1122–1131. doi:10.3109/09638280903410722. [PubMed: 20113311]

37. Seal KH, Bertenthal D, Kumar S. Association between mild traumatic brain injury and mental health problems and self-reported cognitive dysfunction in Iraq and Afghanistan Veterans. J Rehabil Res Dev. 2016;53(2):185–198. doi: 10.1682/JRRD.2014.12.0301 [PubMed: 27148692]

38. Max JE, Koele SL, Castillo CC, et al. Personality change disorder in children and adolescents following traumatic brain injury. J Int Neuropsychol Soc. Mar 2000;6(3):279–289. doi:10.1017/s1355617700633039

39. Centers for Disease Control and Prevention, National Institute of Health, Department of Defense. Report to Congress on Traumatic Brain Injury in the United States: Understanding the Public Health Problem among Current and Former Military Personnel. Published June 2013. Accessed February 15, 2022. https://www.cdc.gov/traumaticbraininjury/pdf/Report_to_Congress_on_Traumatic_Brain_Injury_2013-a.pdf

40. US Department of Veterans Affairs. National Center for Veterans Analysis and Statistics. VA website. Accessed September 24, 2020. https://www.va.gov/vetdata/Veteran_Population.asp

TABLE 1.

Behaviors and Health Indicators from the North Carolina Behavioral Risk Factor Surveillance System, 2018

Behavior or Health Indicator	BRFSS Question	Dichotomized Response
Risk-Taking Behaviors		
Seatbelt Use	"How often do you use seat belts when you drive or ride in a car?"	Less Than Always versus Always
HIV Risk Behaviors	Respondents were asked a list of questions: "I am going to read you a list. When I am done, please tell me if any of the situations apply to you. You do not need to tell me which one. You have used intravenous drugs in the past year. You have been treated for a sexually transmitted or venereal disease in the past year. You have given or received money or drugs in exchange for sex in the past year. You had anal sex without a condom in the past year. You had four or more sex partners in the past year. Do any of these situations apply to you?"	This variable was dichotomized as yes if a respondent answered yes to any of these 5 items on the list or no if they did not answer yes to any of the 5 items on the list.
Problem/Pathological Gambling	This was defined by combining 3 questions: 1) "Have you ever tried to cut down or control your gambling?" 2) "Have you ever lied to family members or friends about how much you gamble or how much money you have lost gambling?" And 3) "Have there been periods for 2 weeks or more when you spent a lot of time thinking about gambling or planning future gambling?"	Respondents were coded in the problem/pathological gambling group if they answered yes to any of these 3 questions. Respondents who answered no to "In the past 12 months, have you gambled or played any games for money?" and answered no to the above 3 questions were coded as not being in the problem/pathological gambling group.
Difficulty Obtaining Health Care		
Current health care coverage	"Do you have any kind of health care coverage, including health insurance, prepaid plans such as HMOs, government plans such as Medicare, or Indian Health Service?"	Yes versus No
Didn't see a doctor due to health care cost in the past 12 months	"Was there a time in the past 12 months when you needed to see a doctor but could not because of cost?"	Yes versus No
Recent routine medical check-up	"About how long has it been since you last visited a doctor for a routine checkup?"	This variable was dichotomized as yes if the respondent answered they had a checkup in the past year (anytime less than 12 months ago) and no if the respondent answered they had a checkup a year or more ago or never
Health Status		
General Health	"Would you say that in general your health is _____?"	Poor/Fair versus Good/Very Good/Excellent
Mental Health	"Now thinking about your mental health, which includes stress, depression, and problems with emotions, for how many days during the past 30 days was your mental health not good?"	This variable was dichotomized as not good (≥ 14 days of metal health not good) and good (< 14 days of mental health not good).
Sleep	"On average, how many hours of sleep do you get in a 24-hour period?"	< 7 hours versus ≥ 7 hours

N C Med J. Author manuscript; available in PMC 2023 May 01.

TABLE 2.

Characteristics of Adult Respondents in North Carolina Behavioral Risk Factor Surveillance System, 2018[a]

Characteristic	N	Weighted Percentage or Mean	95% CI
Sex			
Males	1,609	46.3	44.3–48.4
Females	1,960	53.7	51.6–55.7
Age			
Median	3,519	49.6	48.5–50.7
Race/ethnicity			
Non-Hispanic White	2,401	67.2	65.3–69.2
Non-Hispanic Black	695	21.4	19.7–23.2
Non-Hispanic Other[b]	154	4.1	3.2–5.0
Hispanic	269	7.3	6.2–8.3
Veteran status			
Yes	486	11.2	10.0–12.5
No	3,083	88.8	87.5–90.0
Marital status			
Married	1,715	52.2	50.1–54.3
Divorced/Widowed/Separated	1,067	22.2	20.6–23.8
Never married	659	21.9	20.2–23.7
A member of an unmarried couple	116	3.7	2.8–4.5
Educational attainment			
Less than high school	412	14.5	12.9–16.1
Completed high school	874	25.6	23.7–27.4
Some college	1,069	34.4	32.4–36.5
Bachelor’s degree or higher	1,208	25.5	23.9–27.1
Employment status			
Currently employed[c]	1,754	55.2	53.2–57.2
Out of work/unable to find work	471	13.1	11.7–14.6

Characteristic	N	Weighted Percentage or Mean	95% CI
Homemaker/student/retired	1,326	31.7	29.8–33.5
Lifetime traumatic brain injury with loss of consciousness			
Yes	911	24.8	23.0–26.6
No	2,659	75.2	73.4–77.0
Age of onset of first tramatic brain injury with loss of consciousness [d]			
Median	854	16.1	15.5–16.8
Number of years since first traumatic brain injury with loss of consciousness [e]			
≤ 20	327	43.7	39.4–47.9
21–40	266	31.6	27.6–35.6
> 40	247	24.7	21.2–28.2
TBI severity [d]			
Mild (LOC < 30 minutes)	698	85.2	82.3–88.0
Moderate (LOC 30 minutes - 24 hours)	73	8.8	6.5–11.1
Severe (LOC > 24 hours)	65	6.1	4.2–7.9
Seatbelt use			
Less than always	250	7.7	6.5–8.9
Always	3,309	92.3	91.1–93.5
HIV risk behaviors			
Yes	173	6.1	5.1–7.2
No	3,390	93.9	92.8–94.9
Problem/Pathological gambling			
Yes	165	5.0	4.0–5.9
No	3,207	95.0	94.1–96.0
Current health care coverage			
Yes	3,089	85.4	83.9–87.0
No	475	14.6	13.0–16.1
Didn’t see a doctor due to health care cost in the past 12 months			
Yes	524	16.3	14.6–17.9

Characteristic	N	Weighted Percentage or Mean	95% CI
No	3,040	83.7	82.1–85.4
Recent routine medical check-up			
Yes	2,900	80.3	78.7–82.0
No	640	19.7	18.0–21.3
General health			
Excellent/Very good/Good	2,760	79.4	77.7–81.0
Fair/Poor	798	20.6	19.0–22.3
Mental health			
Good (<14 days mental health not good)	3,078	87.4	86.0–88.8
Not Good (≥ 14 days mental health not good)	447	12.6	11.2–14.0
Sleep			
< 7 hours	1,167	34.5	32.4–36.5
≥ 7 hours	2,336	65.5	63.5–67.6

[a]The sample only includes individuals who responded to the lifetime traumatic brain injury with loss of consciousness question (N = 3,570)

[b]Includes those who answered that they were “non-Hispanic, Asian, AI/AN, or other”

[c]Includes those who are self-employed

[d]Total does not sum to 911 due to respondents who did not report the age of first traumatic brain injury or refused to answer

[e]Total does not sum to 911 due to respondents who did not report their age, age of first traumatic brain injury, or refused to answer

TABLE 3.

Adjusted Odds Ratio and 95% Confidence Interval for the Relationship between Traumatic Brain Injury Exposure and Health Behaviors: North Carolina Behavioral Risk Factor Surveillance System, 2018

	Seatbelt Use[a,b,c]			HIV Risk Behaviors[b,c]			Problem/Pathological Gambling		
	Less Than Always versus Always			Yes versus No			Yes versus No		
Characteristic	**OR or Estimate**	**95% CI**	**P-value**	**OR or Estimate**	**95% CI**	***P*-value**	**OR or Estimate**	**95% CI**	***P*-value**
Lifetime traumatic brain injury with loss of consciousness									
Yes	1.7	1.2–2.4	<.01[i]	1.7	1.1–2.6	.01[i]	-	-	-
No	REF			REF			-	-	-
Number of years since first traumatic brain injury with loss of consciousness[g]									
Continuous	−2.0	−4.9–0.9	.18	0.04	−2.6–2.7	.98	ǂ	ǂ	ǂ

	Current Health Care Coverage			Didn't See a Doctor due to Health Care Cost in the Past 12 Months[a,b,c,d,e,f]			Recent Routine Check-up[a,b,c,e,f]		
	No versus Yes			Yes versus No			No versus Yes		
Characteristic	**OR or Estimate**	**95% CI**	***P*-value**	**OR or Estimate**	**95% CI**	***P*-value**	**OR or Estimate**	**95% CI**	***P*-value**
Lifetime traumatic brain injury with loss of consciousness									
Yes	-	-	-	1.3	1.0–1.8[h]	.04[i]	1.5	1.2–2.0	<.01[i]
No	-	-	-	REF			REF		
Number of years since first traumatic brain injury with loss of consciousness[g]									
Continuous	ǂ	ǂ	ǂ	−0.7	−3.6–2.3	.66	1.9	−0.3–4.2	.09

	General Health[b,c,f]			Mental Health[a,b,c,f]			Sleep[b,d,f]		
	Fair/Poor versus Excellent/Very Good/Good			Fair/Poor versus Great/Good			< 7 hours Fair/Poor versus > 7 hours		
Characteristic	**OR or Estimate**	**95% CI**	***P*-value**	**OR or Estimate**	**95% CI**	***P*-value**	**OR or Estimate**	**95% CI**	***P*-value**
Lifetime traumatic brain injury with loss of consciousness									
Yes	1.8	1.4–2.3	<.0001[i]	2.1	1.6–2.8	<.0001[i]	1.5	1.2–1.8	<.001[i]
No	REF			REF					REF
Number of years since first traumatic brain injury with loss of consciousness[g]									

Continuous	-	-	-	−0.7	−3.9–2.5	0.74	-	-	-

Abbreviations: OR = Odds Ratio, CI = Confidence Interval

[a]Outcome adjusted for by sex

[b]Outcome adjusted for by age

[c]Outcome adjusted for by marital status

[d]Outcome adjusted for by race/ethnicity

[e]Outcome adjusted for by veteran status

[f]Outcome adjusted for by education and employment

[g]Analyses limited to those who replied yes to lifetime traumatic brain injury with loss of consciousness question

[h]Before rounding, the confidence interval was 1.01 – 1.78, so it is included here and the OR is considered significantly different than 1.0

[i]Results are $P < 0.05$

[-]Indicates no modeling was conducted due to lack of significance in the bivariate model

[ǂ]Indicates no modeling was conducted due to lack of significance in the primary outcome of lifetime traumatic brain injury with loss of consciousness