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CLINICAL RESEARCH ARTICLE

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# Is lifetime traumatic brain injury a risk factor for mild cognitive impairment in veterans compared to non-veterans?

Rebecca Akhanemhe[a], Sharon A. M. Stevelink [a,b], Anne Corbett[c], Clive Ballard[c], Helen Brooker[c], Bryon Creese[d], Dag Aarsland[e], Adam Hampshire[f] and Neil Greenberg[a]

[a]King's Centre for Military Health Research, Department of Psychological Medicine, Institute for Psychiatry, Psychology & Neuroscience, King's College London, London, UK; [b]Department of Psychological Medicine, Institute for Psychiatry, Psychology & Neuroscience, King's College London, London, UK; [c]University of Exeter, Exeter, UK; [d]Division of Psychology, Department of Life Sciences, Brunel University London, London, UK; [e]Department of Old Age Psychiatry, Institute of Psychiatry, Psychology, and Neuroscience, King's College London, London, UK; [f]Department of Medicine, Imperial College London, London, UK

## ABSTRACT

**Background:** Traumatic brain injury (TBI) is prevalent in veterans and may occur at any stages of their life (before, during, or after military service). This is of particular concern, as previous evidence in the general population has identified TBI as a strong risk factor for mild cognitive impairment (MCI), a known precursor of dementia.

**Objectives:** This study aimed to investigate whether exposure to at least one TBI across the lifetime was a risk factor for MCI in ageing UK veterans compared to non-veterans.

**Method:** This cross-sectional study comprised of data from PROTECT, a cohort study comprising UK veterans and non-veterans aged ≥ 50 years at baseline. Veteran and TBI status were self-reported using the Military Service History Questionnaire (MSHQ) and the Brain Injury Screening Questionnaire (BISQ), respectively. MCI was the outcome of interest, and was defined as subjective cognitive impairment and objective cognitive impairment.

**Results:** The sample population comprised of veterans ($n = 701$) and non-veterans ($n = 12{,}389$). TBI was a significant risk factor for MCI in the overall sample (OR = 1.21, 95% CI 1.11–1.31) compared to individuals without TBI. The prevalence of TBI was significantly higher in veterans compared to non-veterans (69.9% vs 59.5%, $p < .001$). There was no significant difference in the risk of MCI between veterans with TBI and non-veterans with TBI (OR = 1.19, 95% CI 0.98–1.45).

**Conclusion:** TBI remains an important risk factor for MCI, irrespective of veteran status. The clinical implications indicate the need for early intervention for MCI prevention after TBI.

## ¿Es el traumatismo encéfalocraneano a lo largo de la vida un factor de riesgo de deterioro cognitivo leve en los veteranos en comparación con los no veteranos?

**Antecedentes:** El traumatismo encéfalocraneano (TEC) es frecuente en veteranos, el cual puede ocurrir en cualquier etapa de sus vidas (antes, durante o después del servicio militar). Esto es motivo de preocupación, ya que evidencia previa en la población general ha identificado al TEC como un fuerte factor de riesgo de Deterioro Cognitivo Leve (DCL), un precursor conocido de demencia.

**Objetivo:** Este estudio tuvo como objetivo investigar si la exposición a al menos un Traumatismo encéfalocraneano a lo largo de la vida era un factor de riesgo de Deterioro Cognitivo Leve en veteranos del Reino Unido en comparación con no veteranos.

**Método:** Este estudio de corte transversal incluyó datos de PROTECT, un estudio de cohorte que incluye a veteranos y no veteranos del Reino Unido de ≥50 años al inicio del estudio. El estatus de veterano y de Traumatismo encéfalocraneano (TEC) se auto-reportaron utilizando el Cuestionario de Historia de Servicio Militar (MSHQ, por sus siglas en inglés) y el Cuestionario de Detección de Traumatismo encéfalocraneano (BISQ, por sus siglas en inglés), respectivamente. El Deterioro Cognitivo Leve (DCL) fue el resultado de interés, definido como deterioro cognitivo subjetivo y deterioro cognitivo objetivo.

**Resultados:** La muestra poblacional incluyó a veteranos ($n = 701$) y no veteranos ($n = 12.389$). El Traumatismo encéfalocraneano (TEC) fue un factor de riesgo significativo de Deterioro Cognitivo Leve (DCL) en la muestra total (OR = 1.21, IC del 95% 1.11–1.31) en comparación con individuos sin TEC. La prevalencia de TEC fue significativamente mayor en veteranos en comparación con no veteranos (69.9% vs 59.5%, $p < .001$). No hubo diferencia significativa en el riesgo de DCL entre veteranos con TEC y no veteranos con TEC (OR = 1.19, IC del 95% 0.98–1.45).

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## PALABRAS CLAVES

Traumatismo encéfalocraneano; deterioro cognitivo leve; veteranos; no veteranos; población envejeciendo

## HIGHLIGHTS

- Data from the PROTECT study, a longitudinal study comprising over 25,000 middle-aged and ageing adults in the UK, were used in this first UK comparative study to explore the association between a lifetime history of traumatic brain injury (TBI) and mild cognitive impairment (MCI) in UK veterans and non-veterans.
- Lifetime TBI was more prevalent in veterans compared to non-veterans. TBI events in military veterans could be attributed to non-military events.
- Exposure to a history of TBI irrespective of veteran status increased the risk of MCI by 21% compared to adults with no history of TBI.
- The risk of MCI did not significantly differ between veterans and non-veterans with TBI.

**CONTACT** Sharon A. M. Stevelink Sharon.stevelink@kcl.ac.uk King's Centre for Military Health Research, King's College London, Weston Education Centre, London SE5 9RJ, UK

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**Conclusión:** El Traumatismo encéfalocraneano (TEC) continúa siendo un factor de riesgo significativo de Deterioro Cognitivo Leve (DCL), independiente del estatus de veterano. Las implicaciones clínicas sugieren la necesidad de intervenciones tempranas para la prevención de DCL después de un TEC.

## 1. Introduction

Traumatic brain injury (TBI) has been identified as a public health concern as it is estimated to impact 69 million people worldwide, and is commonly reported in North America and Europe (Dewan et al., 2019). In the UK, TBI was identified as the leading cause of hospital visits, impacting approximately 1.4 million (2%) of the general population (Lawrence et al., 2016), which was attributed to various causes, such as vehicular accidents (Dewan et al., 2019).

While TBI has been recognized in the general population, research has also explored TBI in serving military personnel and veterans (Risdall & Menon, 2011). This is a result of recent conflicts in Iraq and Afghanistan that led to a rise in reported mild TBI events. Mild TBI was labelled as a 'signature injury', impacting up to 4% of active members of the UK Armed Forces (Risdall & Menon, 2011; Rona et al., 2012; Snell & Halter, 2010). However, this was not inclusive of all TBI events, as previous studies have found that military personnel and veterans are vulnerable to acquiring TBI of all severities (mild to severe) (Barnes et al., 2018).

In up to 50% of cases, individuals may experience cognitive symptoms post-injury, which do not necessarily depend on brain injuries being sustained in moderate or severe TBI, but can also be seen in mild TBI (McInnes et al., 2017). Also considering age, cognitive symptoms that are present longer than the post-injury period (McInnes et al., 2017) can increase the risk of long-term cognitive disorders, such as mild cognitive impairment (MCI) and related disorders such as dementia (Calvillo & Irimia, 2020; Gardner et al., 2014; Li et al., 2016; Petersen et al., 2019, Petersen et al., 2020). Supporting evidence from adults (in the general population) with a history of TBI indicated that the risk of MCI increased compared to those without TBI (LoBue et al., 2016), and led to an earlier diagnosis of MCI in adults with TBI. Similarly identified in the US veteran population, previous studies found a strong association between TBI and cognitive decline or dementia (Barnes et al., 2018; Kaup et al., 2017; Peltz et al., 2017).

The evidence presented reflects previous efforts to understand the individual relationship between TBI and MCI or cognitive changes in the general (i.e. non-veteran) and veteran population. However, differences in the association between TBI and MCI in veterans and the general population are yet to be elucidated in the UK. Given that no studies have made this comparison in the UK, it is important to address this gap in our understanding. This study has two aims: (1) to explore whether there is an association between exposure to at least one lifetime TBI and MCI in the overall sample (including both veterans and non-veterans); and (2) to explore whether the risk of MCI differs between veterans and non-veterans with at least one lifetime TBI event. Differences in each aim between the groups were further scrutinized by including other possible confounders, including sociodemographic factors, family history of dementia (FHD), and mental and physical ill-health.

## 2. Methods

### 2.1. Study design and population

We used cross-sectional data from the PROTECT study (Huntley et al., 2018). In total, 18,398 participants took part in the PROTECT TBI nested cross-sectional study in 2019. These data were matched to data from the main PROTECT study of participants who completed their assessments in 2019, irrespective of their study status (i.e. baseline, year 1, etc.). Data were included in the current study if the inclusion criteria were fulfilled: age $\geq$ 50 years at baseline, absence of dementia or any neurodegenerative disorder, have completed the Military Service History Questionnaire (MSHQ), and the Brain Injury Screening Questionnaire (BISQ) (Dams-O'Connor et al., 2014), and have been exposed to at least one TBI event throughout their lifetime.

### 2.2. Independent variables

Veteran status was the primary independent variable of interest, which was confirmed from question 2 of the MSHQ (see Supplementary material A). Participants were stratified as: veterans, which was defined according to the UK definition – serving at least one day in the Armed Forces (Burdett et al., 2013); and non-veterans (this excluded participants who were still serving in the Armed Forces).

The other independent variable was lifetime TBI history, which was defined solely using part A of the BISQ (Dams-O'Connor et al., 2014). TBI status was categorized as TBI present if they confirmed that they had sustained at least one head injury throughout their lifetime (see Supplementary material B for more details on scoring and classification).

### 2.3. Outcome

MCI was the outcome in this study. This was defined similarly to the International Working Group (Winblad et al., 2004). Participants who fitted the criteria reported subjective cognitive decline (SCD) in the Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE) (average score ≥ 3.01) (Jansen et al., 2008; Jorm, 1994, 2004) and performed ≥ 1 standard deviation below the mean in the digit span, self-ordered search, verbal reasoning, paired associate learning test, Switching Stroop test part A, or Trail Making Test part B (Arnett & Labovitz, 1995; Baddeley, 1968; Desai et al., 2020; Eraydin et al., 2019; Jensen, 1965). Participants who fitted the criteria were classified as MCI and those who did not were classified as cognitively normal.

### 2.4. Covariates

Other TBI variables of interest were explored from the BISQ (Dams-O'Connor et al., 2014) (see Supplementary material B). (1) The frequency of TBI events was grouped as: none, once, or twice or more. (2) TBI symptoms was classified as: no TBI, TBI without loss of consciousness (LOC) altered state of consciousness (ASC), TBI with LOC only, TBI with ASC only, or TBI with LOC and ASC. (3) The frequency of LOC and ASC were grouped as: none, once, twice or more. (4) The causes of TBI included a list of 20 events, and were classified as present or absent.

We obtained additional data to be used as covariates:

(1) Sociodemographic data: age group (middle aged: 50–64 years; older adults: ≥ 65 years), gender (male, female), educational level (secondary, post-secondary, vocational, university), ethnicity (white, ethnic minorities), marital status [living in a relationship (married, cohabiting, civil partnership), was previously in a relationship (divorced, separated, widowed), single], employment status (employed, retired, unemployed), and annual income (< £36,000, £36,000–£60,000, > £60,000).

(2) Mental health was measured. This included any mental disorder (AMD) [probable depression caseness using the Patient Health Questionnaire-9 items (PHQ-9) with a score ≥ 7 (Kroenke et al., 2001) or probable post-traumatic stress disorder (PTSD) using the PTSD Checklist-6 items (PCL-6) with a score ≥ 13 (Lang & Stein, 2005), or probable anxiety disorder using the Generalized Anxiety Disorder Questionnaire 7 items (GAD-7) with a score ≥ 7 (Spitzer et al., 2006)]. Probable alcohol use disorder (AUD) was measured using the Alcohol Use Disorders Identification Test (AUDIT) with a score ≥ 8 for caseness (Babor et al., 2001; Bush et al., 1998).

(4) Cardiovascular health (CVH) factors were assessed, including obesity, using a body mass index ≥ 30 kg/m$^2$ (National Health Service, 2023), and stroke and high blood pressure, through self-report or medication report.

(5) Family history of dementia (FHD) was self-reported. If a participant responded yes to having a first degree relative with any of the subtypes of dementia, they were classed as 'family history present', and if they responded no, they were classed as 'family history absent'.

(6) Military service history variables were derived from the MHSQ, including: duration of service (< 4 years, ≥ 4 years), branch [Naval services (Royal Navy and Royal Marines), British Army, Royal Air Force], deployment history (yes or no), and last rank. Last rank was divided into Private or Non-Commissioned Officer (NCO), Officer and other.

### 2.5. Data analysis

Baseline summary characteristics were described for the overall sample and by veteran status. Differences between the groups were compared using the chi-squared or Fisher's Exact test. The risk of MCI was calculated in a series of unadjusted binomial logistic regression models, comparing: (a) participants with no TBI (reference category) and participants with TBI in the overall sample; and (b) non-veterans with TBI (reference category) and veterans with TBI. Following this, a series of independent adjusted binomial logistic regression models was conducted controlling for covariates, based on prior research (Greenberg et al., 2020; Livingston et al., 2017): Model 1: sociodemographic (annual income was excluded from this model as it was expected to highly correlate with educational level) (Stryzhak, 2020); Model 2: FHD; Model 3: mental health; and Model 4: CVH.

Reported outputs from the binomial logistic regression models included the odds ratio (OR), adjusted odds ratio (aOR) for the multivariate models, and 95% confidence interval (CI). CIs that overlapped above or below 1 were indicative of a non-significant risk factor; CI values that overlapped between groups were indicative of no difference between the groups. Postestimation included: (1) Hosmer and Lemeshow's goodness-of-fit test, where $p > .05$ indicated a good fit; and (2) multicollinearity using the variance inflation factor (VIF) to determine any intercorrelation between the variables, where VIF < 10 for each predictor was indicative of no multicollinearity. A sensitivity analysis was conducted to explore the relationship between the covariates in the logistic regression models and a positive TBI status, presenting the OR and CI. Statistical analyses were conducted using STATA version 17.0.

#### 2.5.1. Missing data

The proportion of missing data was minimal (6%). A binomial logistic regression assessed the level of independence between the level of missingness in each variable and a variable with complete data. The outcome showed that the missing data were missing completely at random ($p \geq .05$); therefore, the data were analysed using complete case analysis.

## 3. Results

The final sample size of this study was 13,090, comprising 701 (5.4%) veterans and 12,389 (94.6%) non-veterans (Figure 1).

### 3.1. Descriptive summary of sample characteristics

Table 1 summarizes the baseline characteristics of veterans and non-veterans. There was a significant association between age and veteran status, as a greater proportion of veterans was in the older (≥ 65 years) age group compared to non-veterans (56.8% vs 42.2%). A significant relationship between gender and veteran status was noted, as a greater proportion of veterans was male compared to non-veterans (61.8% vs 22.4%). Over one-quarter of the overall sample were classified as having MCI (27.9%). The prevalence of MCI significantly differed between veterans and non-veterans (31.7% vs 27.6%).

Table 2 summarizes the TBI history of veterans and non-veterans. The prevalence of at least one TBI was significantly higher in veterans compared to non-veterans (69.9% vs 59.5%). Over half of the veterans had encountered a TBI twice or more compared to non-veterans (53.1% vs 42.8%). The top five events attributed to TBI in veterans were other unspecified events (23.8%), any other sports (20.1%), playground (12.2%), vehicular accidents (12%), and hit by a falling object (10.8%). The top five events attributed to TBI was similarly observed in non-veterans, although TBI due to other events, any other sports, playground, falling object and vehicular accidents was significantly lower in non-veterans compared to veterans.

### 3.2. Risk of MCI by veteran and TBI status

An unadjusted logistic regression model conducted for the overall sample ($n = 13,090$) showed that the risk of MCI significantly increased in individuals with TBI compared to individuals without TBI (OR = 1.21, 95% CI 1.11–1.31) (Table 3a). This remained unchanged after adjusting for sociodemographic factors, FHD, mental ill-health, and CVH. A closer examination of the risk of MCI in veterans and non-veterans with TBI ($n = 7862$) was explored (Table 3b). The unadjusted logistic regression model showed that there was no significant difference in the risk of MCI between veterans and non-veterans with TBI (OR = 1.19, 95% CI 0.98–1.45).

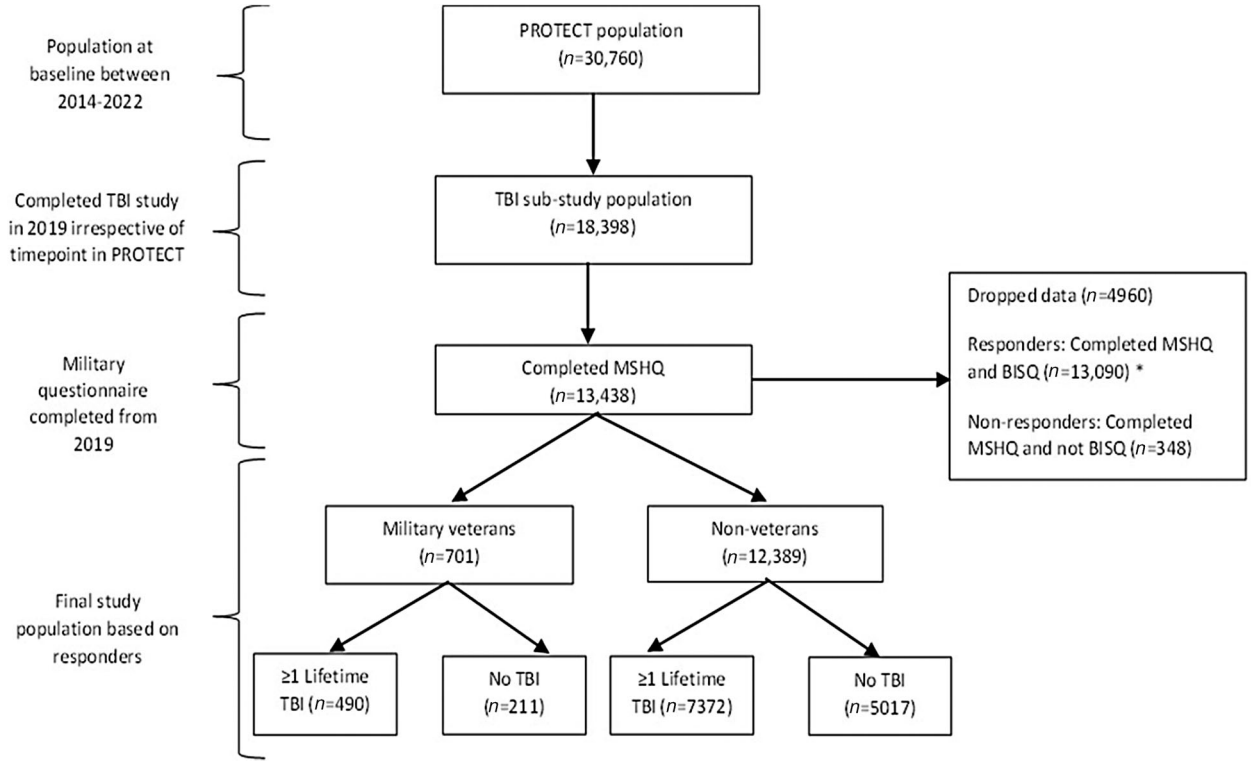


**Figure 1.** Flowchart of sampling, responses, and group allocation. *Final sample size for the analysis. BISQ = Brain Injury Screening Questionnaire, MSHQ = Military Service History Questionnaire; TBI = traumatic brain injury.

**Table 1.** Summary of baseline characteristics in the overall sample and by veteran status.

| | Overall sample ($N = 13,090$) | Veterans ($N = 701$) | Non-veterans ($N = 12,389$) | $p$ |
|---|---|---|---|---|
| Age group (years) | | | | < .001* |
| 50–64 | 3728 (57.0) | 153 (43.2) | 3575 (57.8) | |
| ≥ 65 | 2812 (43.0) | 201 (56.8) | 2611 (42.2) | |
| Gender, Male | 2875 (24.5) | 386 (61.8) | 2489 (22.4) | < .001* |
| Educational level | | | | < .001* |
| Secondary | 1356 (11.5) | 109 (17.4) | 1247 (11.2) | |
| Post-secondary | 1267 (10.8) | 79 (12.6) | 1188 (10.7) | |
| Vocational | 2328 (19.8) | 157 (25.1) | 2171 (19.5) | |
| University | 6807 (57.9) | 280 (44.8) | 6527 (58.6) | |
| Annual income (£) | | | | .003* |
| ≤ 36,000 | 5769 (49.6) | 350 (54.4) | 5419 (49.3) | |
| 36,001–60,000 | 3369 (29.0) | 189 (29.3) | 3180 (28.9) | |
| ≥ 60,001 | 2500 (21.4) | 105 (16.3) | 2395 (21.8) | |
| Employment | | | | < .001* |
| Employed | 4449 (37.9) | 183 (29.3) | 4266 (38.4) | |
| Retired | 6996 (59.6) | 431 (69.1) | 6565 (59.0) | |
| Unemployed | 301 (2.6) | 10 (1.6) | 291 (2.6) | |
| Marital status | | | | .145 |
| LR | 8801 (74.9) | 476 (76.2) | 8325 (74.8) | |
| PR | 2206 (18.8) | 121 (19.4) | 2085 (18.7) | |
| Single | 745 (6.3) | 28 (4.5) | 717 (6.4) | |
| Ethnicity, white | 11,550 (98.2) | 618 (98.9) | 10,932 (98.2) | .206 |
| Duration | – | | – | – |
| ≤ 4 years | | 295 (42.1) | | |
| > 4 years | | 406 (57.9) | | |
| Deployment history (Yes) | – | 230 (32.8) | – | – |
| Branch of service | – | | – | – |
| Naval Services | | 178 (25.4) | | |
| British Army | | 303 (43.2) | | |
| Royal Air Force | | 220 (31.4) | | |
| Rank | – | | – | – |
| Private or NCO | | 406 (58.3) | | |
| Officer | | 255 (36.6) | | |
| Other | | 35 (5.0) | | |
| MCI (positive) | 3337 (27.9) | 205 (31.7) | 3132 (27.6) | .024* |
| AMD caseness | 1790 (14.5) | 83 (12.6) | 1707 (14.6) | .0155* |
| Probable AUD | 871 (7.1) | 65 (9.9) | 806 (6.9) | .004* |
| High blood pressure (Yes) | 3353 (26.3) | 236 (35.0) | 3117 (25.9) | < .001* |
| Stroke (Yes) | 214 (1.7) | 16 (2.4) | 198 (1.6) | .151 |
| Obesity present | 1900 (14.9) | 111 (16.5) | 1789 (14.8) | .249 |
| FHD (Yes) | 3851 (29.6) | 169 (24.3) | 3682 (29.9) | .002 |

Note: Data are shown as $n$ (column percentage). Numbers may not add up owing to missing data.
AMD = any mental disorder; AUD = alcohol use disorder; FHD = family history of dementia; LR = living in a relationship; MCI = mild cognitive impairment; NCO = Non-Commissioned Officer; PR = previously in a relationship.
The chi-squared test was used to calculate the associations between military veterans and non-veterans for categorical variables.
*Significant at $p \leq .05$.

This remained unchanged after adjusting for socio-demographic factors, FHD, mental ill-health, and CVH.

Postestimation analysis included the Hosmer and Lemeshow's goodness-of-fit test, which showed that the unadjusted and each adjusted model was a good fit ($p > .05$). The VIF was conducted to assess multicollinearity also in the unadjusted and each adjusted model which showed no multicollinearity as the VIF <10.

Table 4 presents the outcomes from a sensitivity analysis conducted to explore the relationship between the covariates and a positive TBI status. In the overall sample, a decreased risk of TBI was significantly associated with being female (OR=0.52, 95% CI 0.47-0.57) and a FHD (OR=0.92, 95% CI 0.85-0.99). An increased risk of TBI was significantly associated with an unemployed status (OR=1.25, 95% CI 0.85-0.99), education (all levels), with AMD caseness (OR=1.65, 95% CI 1.48-1.84), and with probable AUD (OR=1.61, 95% CI 1.38-1.87).

## 4. Discussion

### 4.1. Principal findings

This cross-sectional study of 13,090 veterans and non-veterans had notable findings. The first observation was that at least one lifetime TBI was more prevalent in veterans compared to non-veterans. Veterans were more likely to report TBI due to events unrelated to serving in the military, including vehicular accidents, sports, activities in the playground, and other events not specified. Secondly, logistic regression models showed that TBI increased the risk of MCI in the overall sample (irrespective of veteran status). However, the risk of MCI did not significantly differ between veterans and non-veterans with TBI, even after adjusting for

**Table 2.** Summary of baseline traumatic brain injury (TBI) history in the overall sample and by veteran status.

| | Overall ($N = 13,090$) | Veterans ($N = 701$) | Non-veterans ($N = 12,389$) | $p$ |
|---|---|---|---|---|
| ≥ 1 Lifetime TBI status | | | | < .001* |
| TBI present | 7862 (60.1) | 490 (69.9) | 7372 (59.5) | |
| Frequency of TBI events | | | | < .001* |
| None | 4878 (37.3) | 199 (28.4) | 4679 (37.8) | |
| Once | 2532 (19.3) | 130 (18.5) | 2402 (19.4) | |
| Twice or more | 5680 (43.4) | 372 (53.1) | 5308 (42.8) | |
| TBI with symptoms of LOC and ASC | | | | < .001* |
| No TBI | 5228 (39.9) | 211 (30.1) | 5017 (40.5) | |
| TBI without LOC and ASC | 2,942 (22.5) | 143 (20.4) | 2799 (22.6) | |
| TBI with LOC only | 740 (5.7) | 38 (5.4) | 702 (5.7) | |
| TBI with ASC only | 2,227 (17.0) | 149 (21.3) | 2078 (16.8) | |
| TBI with LOC and ASC | 1,953 (14.9) | 160 (22.8) | 1793 (14.5) | |
| Frequency of LOC[a] | | | | .003* |
| None | 5100 (64.9) | 289 (58.9) | 4811 (65.3) | |
| Once | 1608 (20.5) | 105 (21.4) | 1503 (20.4) | |
| Twice or more | 1154 (14.7) | 96 (19.6) | 1058 (14.4) | |
| Frequency of ASC[a] | | | | < .001* |
| None | 3634 (46.2) | 177 (36.1) | 3457 (46.9) | |
| Once | 2001 (25.5) | 125 (25.5) | 1876 (25.5) | |
| Twice or more | 2227 (28.3) | 188 (38.4) | 2039 (27.7) | |
| Event history | | | | |
| Other (unspecified) | 2653 (20.3) | 167 (23.8) | 2486 (20.1) | .016* |
| Any other sports | 1428 (10.9) | 141 (20.1) | 1287 (10.4) | < .001* |
| Hit by a falling object | 1120 (8.6) | 76 (10.8) | 1044 (8.4) | .026* |
| Playground | 1124 (8.6) | 86 (12.2) | 1038 (8.4) | < .001* |
| Vehicular accidents | 1075 (8.2) | 84 (12.0) | 991 (8.0) | < .001* |
| Biking | 957 (7.3) | 71 (10.1) | 886 (7.2) | .003* |
| Fainting | 907 (6.9) | 44 (6.3) | 863 (7.0) | .485 |
| Hit by equipment | 870 (6.7) | 64 (9.1) | 806 (6.5) | .007* |
| Falling downstairs | 766 (5.9) | 37 (5.3) | 729 (5.9) | .506 |
| Skiing/snowboarding | 688 (5.3) | 48 (6.9) | 640 (5.2) | .052 |
| Horseback riding | 637 (4.9) | 30 (4.3) | 607 (4.9) | .458 |
| Physically abused | 583 (4.5) | 34 (4.8) | 549 (4.4) | .601 |
| Assaulted or mugged | 536 (4.1) | 44 (6.3) | 492 (4.0) | .003* |
| Falling from a high place | 387 (3.0) | 31 (4.4) | 356 (2.9) | .019* |
| Motorcycle terrain accidents | 363 (2.8) | 38 (5.4) | 325 (2.6) | < .001* |
| Diving into water | 331 (2.5) | 33 (4.7) | 298 (2.4) | < .001* |
| Pedestrian hit by a vehicle | 265 (2.0) | 18 (2.6) | 247 (2.0) | .294 |
| Drug or alcohol blackout | 177 (1.4) | 14 (2.0) | 163 (1.3) | .129 |
| Rollerblade skating | 68 (0.5) | 5 (0.7) | 63 (0.5) | .414[b] |
| Military (i.e. combat) | 21 (0.2) | 15 (2.1) | 6 (0.1) | < .001* |

Note: Data are shown as $n$ (%). Numbers may not add up owing to missing data.
ASC = altered state of consciousness; LOC = loss of consciousness.
The chi-squared test was used to calculate the associations between military veterans and non-veterans for categorical variables.
[a]The analysis was only conducted in those with TBI.
[b]Outcome from Fisher's Exact test (cell ≤ 5).
*Significant at $p \leq .05$.

**Table 3.** Unadjusted and adjusted risk of mild cognitive impairment (MCI) by (a) traumatic brain injury (TBI) status in the overall sample and (b) veteran and TBI status in participants with TBI only.

| | Unadjusted model | Adjusted models | | | |
|---|---|---|---|---|---|
| | | Model 1 | Model 2 | Model 3 | Model 4 |
| | OR (95% CI) | aOR (95% CI) | aOR (95% CI) | aOR (95% CI) | aOR (95% CI) |
| (a) Overall sample ($n = 13,090$) | | | | | |
| TBI absent | 1 (Reference) | 1 (Reference) | 1 (Reference) | 1 (Reference) | 1 (Reference) |
| TBI present | 1.21 (1.11–1.31)* | 1.21 (1.08–1.35)* | 1.19 (1.10–1.30)* | 1.15 (1.06–1.25)* | 1.20 (1.11–1.30)* |
| (b) History of TBI only ($n = 7862$) | | | | | |
| Non-veteran with TBI | 1 (Reference) | 1 (Reference) | 1 (Reference) | 1 (Reference) | 1 (Reference) |
| Veteran with TBI | 1.19 (0.98–1.45) | 0.93 (0.70–1.22) | 1.12 (0.91–1.37) | 1.21 (0.98–1.49) | 1.18 (0.95–1.44) |

Note: Model 1: sociodemographic factors (age, gender, education, ethnicity, employment status, marital status); Model 2: family history of dementia; Model 3: mental health (AMD, probable AUD); Model 4: physical health (obesity, stroke, high blood pressure).
AMD = any mental disorder; aOR = adjusted odds ratio; AUD = alcohol use disorder; CI = confidence interval; OR = odds ratio.
Asterisks added to values in the table by CIs that overlapped 1.

sociodemographic factors, mental ill-health, cardiovascular conditions, and FHD. Therefore, the overall risk of MCI was driven by TBI and not by veteran status.

### 4.2. Proposed explanation of findings

The association between TBI and MCI irrespective of veteran status has possible explanations. The findings of this study showed that both veterans and non-veterans were more likely to endorse non-military TBI events, including any other sports, vehicular accidents, falling objects, playground activities, and unspecified events. First, this shows that behavioural activities could explain these differences, as individuals with TBI were more likely to engage in specific and possibly repetitive behaviours that could increase the risk of

**Table 4.** Relationship between covariates from the adjusted logistic regression models and traumatic brain injury (TBI)

| | Overall sample, OR (95% CI) | Veterans, OR (95% CI) | Non-veterans, OR (95% CI) |
|---|---|---|---|
| **Age group** | | | |
| 50-64 years | 1 (Reference) | 1 (Reference) | 1 (Reference) |
| ≥65 years | 0.91 (0.82–1.01) | 1.45 (0.72–1.85) | 0.89 (0.80–0.98)* |
| **Gender** | | | |
| Male | 1 (Reference) | 1 (Reference) | 1 (Reference) |
| Female | 0.52 (0.47–0.57)* | 0.83 (0.58–1.17) | 0.51 (0.46–0.56)* |
| **Education level** | | | |
| Secondary | 1 (Reference) | 1 (Reference) | 1 (Reference) |
| Post-secondary | 1.20 (1.03–1.40)* | 1.96 (1.06–3.65)* | 1.17 (0.99–1.37) |
| Vocational | 1.30 (1.13–1.48)* | 2.37 (1.40–4.02)* | 1.25 (1.08–1.44)* |
| University | 1.26 (1.12–1.41)* | 1.77 (1.12–2.79)* | 1.24 (1.10–1.41)* |
| **Annual income** | | | |
| ≤£36,000 | 1 (Reference) | 1 (Reference) | 1 (Reference) |
| £36,001-£60,000 | 0.99 (0.91–1.08) | 0.92 (0.63–1.34) | 0.99 (0.91–1.09) |
| ≥£60,001 | 1.16 (1.05–1.28)* | 0.91 (0.57–1.46) | 1.18 (1.07–1.30)* |
| **Employment** | | | |
| Employed | 1 (Reference) | 1 (Reference) | 1 (Reference) |
| Retired | 0.91 (0.84–0.99)* | 1.27 (0.88–1.83) | 0.89 (0.83–0.97)* |
| Unemployed | 1.25 (0.97–1.60) | 2.09 (0.43–10.19) | 1.23 (0.96–1.58) |
| **Marital status** | | | |
| LR | 1 (Reference) | 1 (Reference) | 1 (Reference) |
| PR | 0.92 (0.84–1.02) | 1.30 (0.83–2.04) | 0.91 (0.82–0.99)* |
| Single | 1.05 (0.90–1.23) | 1.41 (0.58–3.38) | 1.04 (0.89–1.23) |
| **Ethnicity** | | | |
| White | 1 (Reference) | 1 (Reference) | 1 (Reference) |
| Ethnic minorities | 1.01 (0.76–1.34) | 2.66 (0.31–22.27) | 0.99 (0.75–1.32) |
| **AMD caseness**[a] | 1.65 (1.48–1.84)* | 1.84 (1.05–3.23)* | 1.65 (1.48–1.84)* |
| **Probable AUD**[a] | 1.61 (1.38–1.87)* | 1.08 (0.62–1.89) | 1.64 (1.40–1.91)* |
| **High blood pressure (Yes)** [a] | 1.06 (0.98–1.16) | 1.48 (1.04–2.12)* | 1.04 (0.95–1.13) |
| **Stroke (Yes)** [a] | 1.12 (0.85–1.48) | 1.31 (0.42–4.11) | 1.09 (0.82–1.45) |
| **Obesity present**[a] | 1.05 (0.95–1.16) | 1.03 (0.66–1.61) | 1.05 (0.95–1.16) |
| **FHD (Yes)** [a] | 0.92 (0.85–0.99)* | 0.69 (0.48–1.00) | 0.94 (0.87–1.02) |

Note: [a]The reference category are participants absent of the factor AMD-Any Mental Disorders, AUD – Alcohol Use Disorders, CI-Confidence interval, FHD-Family history of dementia, LR-Living in a relationship, MCI-Mild Cognitive Impairment, OR-Odds ratio, PR-Previously in a relationship Significance was determined by CIs that overlapped 1. *Significant values

acquiring a TBI compared to individuals with no history of TBI. This is supported by previous research, which found that veterans were likely to engage in high-risk behaviours, such as reckless driving (Bergman et al., 2018; Roushan et al., 2019; Sheppard & Earleywine, 2013), which could inherently result in vehicular accidents. Secondly, events attributed to TBI reported in veterans may be related to gender, as males were predominant in this group. Research has found differences in how men and women acquire their TBI, with women more likely to receive injuries from assault or violence in interpersonal relationships and men more likely to receive work-related injuries from falls and motor vehicle collisions (Chang et al., 2014; Colantonio, 2016; Iverson et al., 2011).

The association between TBI and MCI remained stable even after adjusting for mental ill-health in the overall sample. There are evidence supporting the intermediary role of mental ill-health between TBI and MCI. Previous findings suggested that symptoms of depression or PTSD occurring 6 months post-TBI contribute towards cognitive dysfunction (Rapoport et al., 2005; Seal et al., 2016). Research has shown that individuals who encountered a TBI were likely to have PTSD, as head injuries are often associated with a traumatic event (Veitch et al., 2013). Depression symptoms could emerge from coping with the symptoms of TBI and the impact of TBI on activities of daily living (Veitch et al., 2013). TBI is less likely to cause AUD, and in most instances, AUD precedes TBI acting as a strong predictor (Weil et al., 2018), but some individuals could return to drinking after a TBI (Weil et al., 2018), especially when triggered by social factors such as being single or unemployed (Murphy & Turgoose, 2019).

The findings showed that there was a significant difference in the prevalence of TBI between veterans and non-veterans, which can be explained by some characteristic differences between the groups. First, a higher proportion of veterans was older than non-veterans, and secondly, veterans were predominantly male, unlike the predominance of women in the non-veteran group. These differences can be related to the high prevalence of TBI found in veterans and, therefore, the high prevalence of MCI detected in this group. Epidemiological data suggest that men are approximately 40% more likely to suffer a TBI compared with women in the general adult population, although the sex difference disappears above 75 years of age (Coronado et al., 2012; Faul & Coronado, 2015).

### 4.3. Strengths and limitations

Our study has several strengths. While previous research has explored the association between TBI

and dementia in veterans (Barnes et al., 2018; Greenberg et al., 2020), this study was distinguishable as it was the first known to the authors that made a comparison between UK veterans and non-veterans to explore the association between TBI and MCI. Secondly, this study explored TBI events that occurred across the lifetime compared to previous studies that focused on only military-related TBI (Karr et al., 2014; Rona et al., 2012). This is positive for three reasons. (1) Veterans may have encountered a TBI prior to or post-service; therefore, exploring TBI that occurred at any point in time broadens our knowledge on TBI external to military-related events. (2) Exploring lifetime TBI ensured that a solid comparative analysis could be made between veterans and non-veterans. The strength of the BISQ as a screening tool is that it offers in-depth information regarding TBI history and symptoms based on self-reports. It is a reliable tool for exploring TBI, and being a structured questionnaire, it is preferred over single-item methods (e.g. 'Have you ever had a TBI?'), which may have lower reliability and validity, as some studies suggest that single-item questionnaires regarding TBI history could potentially fail to detect individuals who have experienced a TBI at some point in their life.

There were several limitations to this study. The design of the study was cross-sectional, and therefore we could not assume TBI, and its symptoms were causally related to MCI as we were unable observe trajectories of cognitive status over time compared to related studies (Barnes et al., 2018). This study used the BISQ to identify TBI variables. Since questionnaire relies on self-reported TBI history, it has the potential to lack sensitivity compared to a structured interview, such as the Ohio State University TBI Identification Method (Corrigan & Bogner, 2007), as this may result in participants underreporting or overreporting TBI events and the frequency of injuries (also known as recall bias), especially in participants who did not endorse a TBI event. This study did not use other clinical sections of the BISQ to exclude participants with major neurological or mental health disorders or the severity of TBI, which could influence how the results are interpreted as these factors could also influence cognitive health outcomes.

### 4.4. Future research

Several areas of future research should be considered. First, this research explored key TBI variables, including frequency and symptoms (LOC, ASC), but exploring TBI severity is also an important component of TBI research and would provide a clearer understanding of its association with MCI, as was previously done by US researchers exploring TBI and dementia (Barnes et al., 2018). Secondly, as the relationship between TBI and MCI is biological in nature, it is vital to explore the neural correlates of TBI and MCI by gathering biological data, including neuroimaging, blood biomarkers, and genetic (apolipoprotein-$\varepsilon_4$) data, as this could provide clarity to epidemiological findings.

## 5. Conclusion

In summary, exposure to TBI, irrespective of veteran status, increased the risk of MCI. Future efforts should be directed towards improving prevention strategies and services for TBI and related head injuries (especially in individuals with a complex medical history) through training for healthcare professionals, community support, and support within the military working environment.

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No potential conflict of interest was reported by the authors.

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## Data availability statement

Owing to the nature of the research, for ethical reasons supporting data are not available.

## ORCID

*Sharon A. M. Stevelink* http://orcid.org/0000-0002-7655-7986

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