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Mild Traumatic Brain Injury in UK Military Personnel Returning From Afghanistan and Iraq: Cohort and Cross-sectional Analyses

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Objectives: To assess (*a*) the prevalence of mild traumatic brain injury (mTBI) in UK military personnel deployed to Iraq and/or Afghanistan, (*b*) the risk factors associated with mTBI, and (*c*) the association between mTBI and subsequent postconcussion symptoms (PCS). **Participants:** A total of 4620 personnel deployed to Iraq and/or Afghanistan who completed a questionnaire between 2007 and 2009, of whom 2333 were also studied in 2005, participated in the study. **Main Outcome Measures:** Mild traumatic brain injury during deployment, as identified using a modified version of the Brief Traumatic Brain Injury Screen questionnaire; symptoms associated with PCS in the month before questionnaire completion. **Results:** The prevalence of mTBI was 4.4%, and the prevalence in those with a combat role was 9.5%. Having an mTBI was associated with current symptoms of posttraumatic stress disorder (adjusted odds ratio (AOR), 5.2; 95% confidence interval [CI], 2.3–11.4), alcohol misuse (AOR, 2.3; 95% CI, 1.4–3.7), and multiple physical symptoms (AOR, 2.6; 95% CI, 1.3–5.2). Only 3 of 9 symptoms remained associated with mTBI after adjustment. Psychological distress and alcohol misuse recorded before deployment were associated with subsequent mTBI. **Conclusions:** The prevalence of mTBI in UK military is lower than that in the US military. Symptoms of current posttraumatic stress disorder and alcohol misuse are associated with mTBI. Symptoms of mental disorder predated occurrence of mTBI. The majority PCS were not associated with mTBI.
Key words: *mild traumatic brain injury*, *postconcussion symptoms*, *posttraumatic stress disorder*, *prevalence*

MILD TRAUMATIC BRAIN INJURY (mTBI) is characterized by short-term loss of consciousness (LOC) and/or altered mental state (AMS) as a result of a head injury or blast explosions. Mild traumatic brain injury has emerged as an important concern in the US military[1,2] and, indeed, has been described as the "signature injury" of the current conflicts in Iraq and Afghanistan.[3] A prevalence of 15% was found in a large survey of combat infantry personnel deployed to Iraq.[1] Others have reported estimates from 12% to 23%,[4–7] reaching approximately 40% among injured personnel returning from Iraq or Afghanistan who had been exposed to a blast.[8]

The lack of precision in estimating the prevalence of mTBI in the military is primarily attributable to the fact that a retrospective assessment is made when the person has returned from deployment, not immediately after the injury experience. It may also reflect a substantial overlap with the consequences of psychological trauma such as posttraumatic stress disorder (PTSD) whose symptoms can overlap with, and thus may be misattributed to, mTBI.[1,4,5,9] The prevalence of mTBI has not been studied in the military outside the United States.

For many years, head injury has been associated with postconcussion symptoms (PCS). This is seen as an outcome of mTBI, but its symptoms, which include headache, difficulty in concentrating, irritability, and

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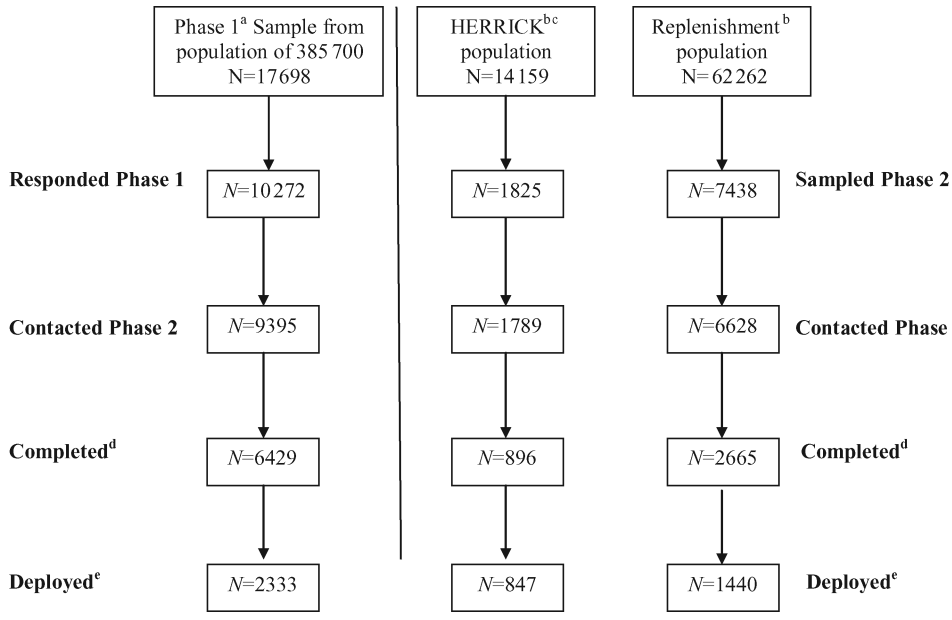

Figure 1. Summary of sampling and response. [a]Cohort sampled at phase 1 in 2003. [b]Additional samples at phase 2 in 2007. [c]HERRICK is the UK military codename for the operation in Afghanistan. [d]Includes deployed and not deployed to Iraq or Afghanistan. [e]Deployed to either Iraq or Afghanistan and completed the deployment section of the phase 2 questionnaire.

memory problems, are nonspecific. In 1 study, there was similar prevalence of these symptoms in those reporting mTBI and controls,[10] and in another study, the association of mTBI and PCS disappeared after adjustment for depression and PTSD.[1] The only study of UK armed forces showed an association between PCS and symptoms of PTSD, but actual occurrence of mTBI had not been recorded.[11]

Between 2007 and 2009, we carried out a large study of the UK armed forces, which included personnel deployed to Iraq and/or Afghanistan. The survey included questions to assess the occurrence of mTBI during deployment and postdeployment, reporting of symptoms of PCS among those deployed to Iraq and Afghanistan. The aims of this article were to describe (*a*) the prevalence of mTBI in UK service personnel deployed to Iraq and/or Afghanistan, (*b*) the risk factors associated with mTBI, including current and previous symptoms of PTSD, psychological distress, multiple physical symptoms (MPS), and alcohol misuse, and (*c*) the association between mTBI during deployment and subsequent PCS symptoms and the extent to which any such associations could be explained by psychiatric comorbidities.

METHODS

Sample

In 2004, we established a cohort study to assess the mental and physical health of UK armed forces (phase 1).[12] The study included a random sample of personnel deployed to Iraq in 2003 (the UK military code name for the 2003 invasion of Iraq was TELIC 1) and another randomly selected group of those who were in the military but had not deployed at that time (ERA sample).[12] We recontacted those who completed the questionnaire in phase 1 and who gave permission for future contact (phase 2). This constituted our follow-up sample. Another 2 samples were added at this stage. First, we included a random sample of those deployed to Afghanistan (code name, Operation HERRICK) between April 2006 and April 2007.[13] This was to ensure sufficient statistical power to explore specific health issues related to deployment to Afghanistan (HERRICK sample). Second, we added a sample based on personnel who had joined the UK armed forces since the start of the original study. They had completed training between April 2003 and April 2007 and could therefore have deployed to Iraq and Afghanistan in the period under consideration (Replenishment sample). This sample was added to ensure that the demographic characteristics, especially age and rank, of the study continued to reflect the current composition of the UK armed forces at the time of sampling in 2007. Regulars and reserves, both serving and those who had subsequently left the services, were included in the study. In this article, we report on personnel who have been deployed to Iraq and/or Afghanistan and have been studied at both phases (follow-up sample) and deployed personnel who were studied at phase 2 alone (HERRICK and Replenishment samples). Figure 1 details the participants included in this article. Further details on sampling

fractions according to engagement type (regular and reserve) are available elsewhere.[13]

The weighted response rate (see analysis) was 68.4% ($N = 6429$) for the follow-up sample, 50.1% ($N = 896$) for the HERRICK sample, and 40.2% ($N = 2665$) for the Replenishment sample. The overall response rate was 56% for phase 2 of the study.[13] As found in all epidemiological studies of the military, responders were more likely to be older, women, officers, regulars, and those who participated in the first phase of the study. Importantly, we have shown no association between responding at phase 2 and baseline mental health outcomes for the follow-up sample.[13] As explained previously, only deployed personnel were included in this analysis.

Data collection for phase 2 started in November 2007 and ended on September 30, 2009, and included personnel who were deployed up to the end of the survey. After an initial mailing of the questionnaire to all participants, data were collected during visits to military bases by the research team or via a second mailing. At least 3 attempts were made to contact participants until contact was made, the person informed us that they no longer wished to take part, or it became clear that no valid address could be obtained.[13]

Measures

The information obtained at phase 2 was collected via a questionnaire that asked about participants' last deployment in Iraq and/or Afghanistan. Possible mTBI was assessed by using a modified version of the Brief Traumatic Brain Injury Screen, which includes an item exploring possible causes of injury–blast, shrapnel fragments, bullet, fall, vehicle accident, and other.[14] There was an option to state that the participant had not suffered an injury during deployment. A second item asked about possible symptoms associated with the injury. These were losing consciousness, being dazed or confused, not remembering the injury, concussion (eg, headache and dizziness), head injury, or none of these. Participants were asked to tick all that applied. Self-report of the duration of any LOC was also obtained to eliminate from the analysis anyone with prolonged LOC. Participants who endorsed at least 1 of these symptoms but not the LOC were classified as having an AMS. We thus created 2 subgroups of mTBI: (1) those with injury and associated LOC with or without symptoms of AMS (mTBI [LOC]) and (2) only injury and AMS but not LOC (mTBI [AMS]). Those reporting head injury alone or reporting no symptoms as the immediate result of the injury were classified as "other injury."

The comorbid disorders that we assessed were PTSD, using as threshold a score of 50 or greater on the PTSD checklist,[15] the symptoms of common mental disorder measured by the General Health Questionnaire-12 (GHQ-12) using as positive a score of 4 or greater,[16] alcohol misuse measured by the Alcohol Use Disorders Identification Test using a score of 16 or more,[17] and MPS experienced in the last month.[18] From the list of 53 symptoms, we removed the 9 PCS described later, leaving 44 symptoms. We have previously defined MPS as a score of 18 or more symptoms endorsed,[12] but we adjusted this to 15 or more to take into account that 9 PCS were removed and analyzed separately. For the follow-up sample, we had available the same measures from phase 1.

The PCS were derived from the list of MPS described previously and consisted of headache, dizziness, irritability or outbursts of anger, double vision, loss of concentration, forgetfulness, ringing in the ears, fatigue, and sleeping difficulties. These were chosen to include the 7 symptoms shown to differentiate between individuals with mTBI and control groups 1 month after head injury[19] and the symptoms used in a previous study of PCS in UK armed forces.[11] Thus, the PCS were not part of Brief Traumatic Brain Injury Screen and were in a different section of the questionnaire as in the questionnaire used in the study by Hoge et al.[1]

Information was also available on the type of engagement (regular or reserve), role during deployment (combat or noncombat, eg, logistics, engineers), time spent outside of base in a hostile area, location of deployment (only Iraq, only Afghanistan, or both), rank (commissioned officer, noncommissioned officer, and other rank), number of deployments, age, sex, educational status, and marital status. In the group that was deployed to both Iraq and Afghanistan, role during deployment and time spent outside of base could be different for each operation; for these individuals, data on role and time outside base were related to the deployment in which a participant reported an injury.

Analysis

All analyses were weighted to take account of sampling fractions and response differences.[13] Reported percentages might not correspond to the numerators and denominators shown because of the weighted analyses.

Frequencies rates were calculated for 4 groups: mTBI (LOC), mTBI (AMS), injury without relevant symptoms at the time of the event (other injury), and no injury. Odds ratios (OR) were calculated in relation to total mTBI (LOC plus AMS), as mTBI (LOC) was uncommon, using as reference group those with injury but without relevant symptoms. Possible risk factors for mTBI, including sociodemographic, service, deployment, and health characteristics, were analyzed first unadjusted, then adjusted for sociodemographic factors, and finally adjusted for service and deployment experience variables (Adjusted OR [AOR]). In the analyses, assessing

association between each PCS at questionnaire completion and mTBI experienced during deployment as an independent factor, in addition to the adjustments for sociodemographic, service, and deployment factors, we adjusted for PTSD and then additionally for alcohol misuse and MPS. We adjusted for MPS (with PCS removed) to determine whether a marker for multiple-symptom endorsement would decrease the association between PCS and mTBI. These analyses were performed separately for the follow-up sample to assess whether PTSD caseness, symptoms of common mental disorder, MPS, and alcohol misuse reported at phase 1 were associated with mTBI reported at phase 2. In the assessment of the strength of the association, we defined associations with an OR of less than 2 as "weak," those with an OR between 2 and 4 as "intermediate," and those with an OR greater than 4 as "strong." All analyses were carried out by using STATA 10 (Stata Corporation, College Station, Texas) using survey (svy) commands as appropriate to take account of the sample and response weights.

The study received ethical approval from the Ministry of Defence's research ethics committee and King's College Hospital local research ethics committee.

RESULTS

Four thousand six hundred twenty of the 9990 participants who completed the questionnaire in phase 2 had deployed to Iraq and/or Afghanistan and completed the mTBI questions. Of the 4620 participants, 2333 (68.9%) were from the follow-up sample, 1440 (21.2%) from the replenishment sample, and 847 (9.9%) from the HERRICK sample.

A total of 203 (4.4%; 95% confidence interval [CI], 3.6%–5.1%) participants fulfilled the criteria for mTBI, of whom 40 (0.7%; 95% CI, 0.5%–1.0%) were classified as mTBI (LOC) and 163 (3.6%; 95% CI, 2.9%–4.3%) as mTBI (AMS). A total of 488 (10.2%; 95% CI, 9.1%–11.2%) participants had sustained injury but without symptoms of mTBI (other injury). The prevalence of mTBI in personnel with a combat role was 9.5% (95% CI, 7.4%–11.5%). Table 1 shows the distributions of mTBI (LOC), mTBI (AMS), other injury, and no injury by demographic, service, and health characteristics. The mTBI categories were more common in the youngest, those with lower education level and lower ranks, and those with a combat role or who spent more time outside the base. The percentage of mTBI (LOC) and mTBI (AMS) did not greatly vary by deployment location, with the exception that there was a slightly higher percentage in the group deployed to both Iraq and Afghanistan. The percentages of PTSD cases and alcohol misuse were higher in mTBI (LOC) and mTBI (AMS) than those with other injury, but there were no differences in relation to the symptoms of common mental disorder (GHQ-12). Current MPS and PCS symptoms were higher in mTBI (LOC) and mTBI (AMS) than other injury. There were no significant differences between the mTBI (LOC) and mTBI (AMS) groups, except that double vision and dizziness in the past month were more frequent in the mTBI (AMS) group, approaching statistical significance ($P = .09$ and $P = .07$, respectively). In the follow-up sample alone, the distribution of health outcomes did not show major differences compared with those in the combined samples, but the percentages in the mTBI (LOC) group were based on only 12 individuals (Table 1).

Blasts, fragments, and vehicle incidents were the mechanisms of injury, with a higher frequency for those with mTBI (LOC) and mTBI (AMS) compared with other injury. Falls were equally common for the 3 injury groups, and bullet as a mechanism of injury was rare but more frequent in those in either mTBI group (Table 2). Seven of the 11 individuals with mTBI who endorsed bullet as the mechanism of injury also endorsed blast, fall, or fragment. Twenty-five of the 37 endorsing fragment as a mechanism of injury also endorsed blast or fall.

As the prevalence of mTBI (LOC) was low and the service, demographic, and health symptoms associated with mTBI (LOC) and mTBI (AMS) were similar, we conducted the remaining analyses by combining these 2 mTBI groups.

Having a combat role, spending more than a month outside the base in a hostile area and not being an officer were associated with mTBI. We did not find other differences (Table 3). The association for role during deployment persisted after adjustment for both demographic and service factors, and the association for time spent outside base persisted for demographic but not for service factors. Rank was no longer associated with mTBI after adjustment. The PTSD, alcohol misuse, and MPS were associated with mTBI regardless of the level of adjustment. The effect size was strong for PTSD and intermediate for alcohol misuse and MPS.

We repeated the analysis on the basis of the follow-up sample alone, adjusting for phase 1 health outcomes and, separately, for phase 2 health outcomes (Table 4). We excluded from this analysis 57 of those with mTBI or other injury shown in Table 1, because the deployment reported at phase 2 predated the completion of their phase 1 questionnaire; thus, their phase 1 health outcomes were later than their phase 2 deployment exposures. Both symptoms of common mental disorder and alcohol misuse assessed at phase 1 (ie, before injury) were associated with subsequent mTBI regardless of the level of adjustment. Although the association between PTSD at phase 1 and reporting of mTBI was not significant, the OR was 2.8. Reporting MPS at phase 1 was not associated with later mTBI. The association

TABLE 1 *Demographic, service, deployment, and health characteristics of the study population*[a,b]

Total sample	mTBI (LOC), *N* = 40 (0.7%)	mTBI (AMS), *N* = 163 (3.6%)	Other injury, *N* = 488 (10.2%)	No injury, *N* = 3929 (85.5%)
Sex				
Males	39 (98.5%)	154 (96.2%)	455 (94.2%)	3566 (92.0%)
Age, y				
<29	28 (66.9%)	93 (62.5%)	254 (50.9%)	1799 (42.6%)
Education				
No qualifications or O levels	25 (71.3%)	79 (53.6%)	204 (47.1%)	1741 (49.5%)
Marital status				
In a relationship	26 (70.5%)	111 (67.8%)	359 (73.2%)	2924 (77.1%)
Service				
Royal Navy	2 (3.4%)	2 (1.0%)	17 (2.4%)	227 (6.4%)
Royal Marines	3 (6.8%)	10 (5.0%)	19 (3.2%)	173 (3.4%)
Army	33 (85.4%)	135 (84.5%)	382 (81.9%)	2719 (70.7%)
Royal Air Force	2 (4.4%)	16 (9.5%)	70 (12.6%)	810 (19.5%)
Rank				
Officer	5 (6.4%)	17 (8.4%)	76 (12.9%)	876 (18.4%)
NCO	19 (52.5%)	94 (60.9%)	285 (65.1%)	2207 (63.1%)
Other ranks	16 (41.1%)	52 (30.8%)	127 (22.0%)	846 (18.5%)
Engagement type				
Regular	33 (89.2%)	135 (91.4%)	414 (90.6%)	3585 (95.3%)
Deployed role				
Combat	25 (58.4%)	86 (55.7%)	145 (31.6%)	885 (23.8%)
Deployed theatre				
Only Iraq	18 (56.6%)	69 (48.9%)	238 (54.1%)	1939 (56.5%)
Only Afghanistan	9 (17.2%)	45 (24.8%)	134 (23.0%)	1135 (24.4%)
Iraq and Afghanistan	13 (26.2%)	49 (26.4%)	116 (22.9%)	855 (19.1%)
No. of deployments				
More than 1	24 (58.9%)	93 (56.1%)	275 (52.2%)	2177 (49.6%)
Time outside base				
None	6 (20.9%)	17 (8.3%)	93 (18.5%)	1093 (28.0%)
Up to 1 mo	10 (17.6%)	51 (32.7%)	179 (39.4%)	1595 (41.3%)
More than 1 mo	24 (61.5%)	92 (59.1%)	211 (42.2%)	1191 (30.7%)
Health outcomes				
PTSD case	5 (11.6%)	30 (18.3%)	23 (4.6%)	109 (3.1%)
GHQ-12 case	15 (33.2%)	53 (32.4%)	126 (28.2%)	654 (17.2%)
MPS case	7 (13.8%)	28 (19.1%)	32 (8.4%)	134 (4.1%)
Alcohol misuse	13 (36.1%)	48 (34.3%)	98 (19.7%)	586 (14.8%)
PCS symptoms				
Headaches	23 (61.4%)	91 (59.5%)	223 (47.3%)	1614 (42.9%)
Irritability/outbursts anger	24 (58.4%)	89 (57.5%)	215 (46.7%)	1309 (34.9%)
Double vision	2 (4.6%)	18 (14.5%)	10 (2.0%)	94 (2.6%)
Forgetfulness	15 (36.4%)	60 (43.3%)	160 (36.3%)	974 (25.6%)
Dizziness	5 (10.4%)	37 (23.2%)	49 (10.7%)	329 (8.9%)
Loss of concentration	19 (46.5%)	72 (44.9%)	145 (33.5%)	843 (22.3%)
Ringing in ears	15 (38.2%)	61 (38.1%)	103 (22.7%)	526 (13.7%)
Fatigue	13 (33.4%)	78 (48.1%)	201 (44.5%)	1282 (34.7%)
Sleeping difficulties	23 (56.3%)	110 (68.7%)	265 (58.5%)	1616 (42.6%)
Only follow-up sample	12 (0.5%)	73 (3.5%)	222 (9.5%)	2026 (86.6%)
Health outcomes				
PTSD case	2 (14.5%)	15 (17.5%)	10 (4.0%)	63 (3.4%)
GHQ-12 case	6 (40.4%)	26 (33.1%)	61 (29.7%)	342 (17.5%)
MPS case	3 (13.4%)	12 (17.6%)	18 (9.9%)	83 (4.5%)
Alcohol misuse	5 (41.6%)	22 (34.3%)	36 (16.1%)	233 (12.2%)

Abbreviations: GHQ-12, General Health Questionnaire-12 (common mental disorders); MPS, multiple physical symptoms; mTBI, mild traumatic brain injury; mTBI (AMS), mTBI with altered mental state; mTBI (LOC), mTBI with loss of consciousness; NCO, noncommissioned officer; PTSD, posttraumatic stress disorder.

[a]The mTBI group was divided into those with loss of consciousness (mTBI [LOC]) and those with altered mental state (mTBI [AMS]) in the total sample ($N = 4620$), and, for health outcomes, in the follow-up sample ($N = 2333$).

[b]Percentages are weighted to take account of sampling fractions and response rates. Some participants did not complete all relevant questions.

TABLE 2 *Mechanism of injury according to mTBI status*[a]

	mTBI (LOC), *N* = 40 (0.7%)	mTBI (AMS), *N* = 163 (3.6%)	Other injury, *N* = 488 (10.2%)
Mechanism of injury,[b] *N* (%)			
Fragment	5 (16.6)	32 (23.6)	31 (6.0)
Bullet	2 (4.6)	9 (6.1)	11 (2.4)
Fall	19 (46.3)	54 (36.5)	216 (42.5)
Vehicle	8 (20.9)	40 (21.0)	66 (12.8)
Blast	18 (46.8)	60 (37.7)	42 (10.1)
Other	4 (17.1)	31 (17.3)	166 (35.5)

Abbreviations: mTBI, mild traumatic brain injury; mTBI (AMS), mTBI with altered mental state; mTBI (LOC), mTBI with loss of consciousness.

[a]The mTBI group was divided into those with loss of consciousness (mTBI [LOC]) and those with altered mental state (mTBI [AMS]).

[b]Participants could endorse more than 1 mechanisms of injury. Percentages are weighted to take account of sampling fractions and response rates.

between phase 2 mental health outcomes and mTBI were generally similar to those in the total sample, except that the association between MPS and mTBI was not significant.

Mild traumatic brain injury during deployment was associated with the later reporting of 6 PCS, the exceptions being forgetfulness, fatigue, and sleeping difficulties. The effect sizes were weak or intermediate, with the exception of double vision (OR = 7). In addition, mTBI was associated with reporting of MPS (Table 5). The AOR slightly increased after adjustment for sociodemographic and service factors and decreased after adjustment for current PTSD. Further adjustment for symptoms of common mental disorder did not modify the associations (results not shown). Additional adjustment for alcohol misuse and MPS modified the association between mTBI and each PCS. The MPS, rather than alcohol misuse, was the factor that decreased the association (results not shown). After adjustment for all the variables, only double vision, headaches, and dizziness remained associated with mTBI.

DISCUSSION

Our main finding is that the prevalence of mTBI was 4.4% in UK service personnel deployed to Iraq and/or Afghanistan, below that reported in US studies using similar methodologies and instruments. This prevalence went up to 9.5% in combat troops, with the most frequently stated injury mechanism being blast injuries.

Most of those who fulfilled the criteria for mTBI (83.1%) had an AMS, with only a minority reporting LOC at the time of injury. More than any service or demographic factor, current PTSD and, to a lesser extent, alcohol misuse and MPS were associated with having experienced mTBI. We also showed that the symptoms of common mental disorder and alcohol misuse, but not MPS, assessed before the reported injury were risk factors for reporting subsequent mTBI. Having a combat role and spending time outside the base in a hostile area increased the risk of an association between mTBI and PCS. However, 6 of the 9 symptoms of PCS were not associated with mTBI after adjustment for PTSD and MPS.

Interpretation of our findings

Prevalence

The prevalence of mTBI in our study was lower than that in the US studies,[1,4–7] in which the prevalence of mTBI were 12%,[5] 15%,[1] and 18.8%[4] and the highest was 22.8%.[7] As predicted, the prevalence was higher in those with a combat role (9.5%) but still lower than that seen in the US studies. The LOC was less frequently reported by those with possible mTBI (17.0%) than by those in the US studies, 32% and 33%.[1,4] The percentage of reported injury, with or without mTBI, in our study was also lower than that in the US studies.[1,6] Comparisons between studies are appropriate because the instrument to assess mTBI were, if not identical, similar between studies.[14] Hoge and colleagues[1] omitted those with head injury with no symptoms, but we included these in the "other injury" group. With 1 exception,[4] the majority of the US studies have been performed in army infantry personnel, while our study included all service branches. This is important because many in the Royal Marines serve in a combat role. Service branch does not explain the discrepancy between the UK and the US studies, as the prevalence of mTBI in the UK army was only 5.1%, still markedly different from the US reports. In comparison with the study of Hoge and colleagues,[1] the percentage of men in our study was slightly lower (92.4% vs 95.5%), the percentage junior enlisted rank was slightly higher (49.7% vs 47.5%), but the percentage of service personnel younger than 30 years was lower in our study (44.3% vs 55.5%). If the age distribution in our study were the same as in the study of Hoge and colleagues,[1] the prevalence of mTBI would have been 4.7% instead of 4.3%.

Possible explanations for our findings could be related to equipment, exposure, and cultural experiences. There is nothing to suggest that the US helmets are less effective than the UK helmets, so this explanation seems implausible. More plausible explanations may be related to the frequency of combat exposure. It is difficult to compare

TABLE 3 *The association between service and mental health characteristics and mTBI status (LOC and AMS combined vs other injury) in the total sample (N varied between 657 and 691 because some participants did not complete all questions)*

	Unadjusted OR (95% CI)	Adjusted for sociodemographic variables,[a] AOR (95% CI)	Adjusted for all confounders,[b] AOR (95% CI)
Service			
Royal Navy	0.56 (0.17–1.83)	0.64 (0.20–2.03)	0.75 (0.20–2.80)
Royal Marines	1.62 (0.71–3.69)	1.66 (0.75–3.67)	1.16 (0.50–2.71)
Army	1.0	1.0	1.0
Royal Air Force	0.66 (0.34–1.29)	0.74 (0.38–1.47)	1.03 (0.48–2.21)
Rank			
Officer	1.0	1.0	1.0
NCO	1.47 (0.77–2.82)	1.16 (0.53–2.53)	1.34 (0.57–3.13)
Other rank	2.38 (1.20–4.73)	1.59 (0.68–3.72)	1.60 (0.64–4.02)
Engagement type			
Regular	1.0	1.0	1.0
Reserve	0.96 (0.55–1.67)	1.16 (0.63–2.15)	1.14 (0.58–2.25)
Deployed role			
Combat	2.78 (1.83–4.20)	3.03 (1.93–4.77)	2.60 (1.57–4.30)
Support/service support	1.0	1.0	1.0
Time outside base			
None	1.0	1.0	1.0
Up to 1 mo	1.35 (0.70–2.60)	1.51 (0.75–3.01)	1.31 (0.63–2.73)
More than a mo	2.49 (1.36–4.58)	2.70 (1.40–5.20)	1.59 (0.75–3.36)
Deployed theatre			
Only Iraq	1.0	1.0	1.0
Only Afghanistan	1.10 (0.68–1.79)	1.07 (0.64–1.79)	1.07 (0.59–1.93)
Iraq and Afghanistan	1.24 (0.77–2.01)	1.29 (0.79–2.12)	1.13 (0.62–2.05)
No. of deployments			
1	1.0	1.0	1.0
2 or more	1.19 (0.79–1.78)	1.22 (0.80–1.86)	1.15 (0.67–1.99)
Health outcomes			
PTSD case	4.32 (2.24–8.31)	5.11 (2.55–10.24)	5.18 (2.34–11.44)
GHQ case	1.23 (0.79–1.90)	1.37 (0.86–2.17)	1.52 (0.94–2.43)
MPS	2.41 (1.29–4.48)	2.82 (1.43–5.54)	2.60 (1.29–5.24)
Alcohol misuse	2.16 (1.37–3.39)	2.09 (1.30–3.34)	2.27 (1.38–3.73)

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; GHQ-12, General Health Questionnaire-12 (common mental disorders); MPS, multiple physical symptoms; mTBI, mild traumatic brain injury; mTBI (LOC), mTBI with loss of consciousness; mTBI (AMS), mTBI with altered mental state; NCO, noncommissioned officer; OR, odds ratio; PTSD, posttraumatic stress disorder.

[a]Adjusted for gender, age (in 5 groups: <25, 25–29, 30–34, 35–39, and >39 years), educational status (in 4 groups), and marital status (3 groups).

[b]In addition, adjusted for service, rank, engagement status, deployed theatre, number of deployments, combat role, and time outside base in hostile area.

the intensity of combat experienced by the 2 coalition forces in Iraq and Afghanistan, as has been discussed previously in relation to the prevalence of PTSD.[20,21] However, we calculated the intensity of combat in terms of the rate of fatalities (deaths in the numerator and average number deployed in a year in the denominator, as a proxy measure of person-years) based on information from the UK Defence Analytical Services and Advice, supplemented with the Internet data giving fatality figures for the US and UK deployed personnel[22] and from a Congress Research Report of US troop levels in Iraq and Afghanistan.[23] The denominator should be considered only as a proxy because it was assumed that the length of deployment was 12 months for the United States and 6 months for the United Kingdom. While this is generally true, particularly for combat troops, there are still variations between services and within services in the 2 countries. The fatality rates in Iraq were higher for the US military (varying from 5.8 to 7.2 per 1000 between 2003 and 2007 for the United States and 1.9 to 8.5 per 1000 for the United Kingdom and decreasing thereafter but always being lower for the UK military), but conversely, in Afghanistan, the rates were higher for UK forces (between 4.8 and 6.3 per 1000 for the United

TABLE 4 *Unadjusted and adjusted association between mTBI status (LOC and AMS combined vs other injury) at phase 2 and mental disorders at phase 1 and phase 2 in the follow-up sample alone (N varied between 250 and 223 because some participants did not complete all questions)*

Health outcomes	Unadjusted OR (95% CI)	Adjusted for sociodemographic factors,[a] AOR (95% CI)	Adjusted for all confounders,[b] AOR (95% CI)
Phase 1			
PTSD case	3.14 (0.86–11.54)	3.26 (0.98–10.87)	2.79 (0.72–10.82)
GHQ-12	2.27 (1.11–4.65)	2.35 (1.10–5.01)	2.74 (1.12–6.67)
MPS	1.96 (0.63–6.07)	1.81 (0.55–5.96)	2.16 (0.66–7.00)
Alcohol misuse	5.72 (2.71–12.07)	5.33 (2.26–12.58)	7.44 (2.94–18.88)
Phase 2			
PTSD case	4.22 (1.41–12.69)	6.06 (1.93–19.01)	6.16 (1.67–22.71)
GHQ-12	1.26 (0.62–2.53)	1.36 (0.63–2.92)	2.10 (0.93–4.73)
MPS	1.48 (0.55–4.00)	1.78 (0.61–5.19)	1.39 (0.48–4.00)
Alcohol misuse	2.96 (1.38–6.36)	3.20 (1.44–7.10)	4.31 (1.79–10.38)

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; GHQ-12, General Health Questionnaire-12 (common mental disorders); MPS, multiple physical symptoms; mTBI, mild traumatic brain injury; mTBI (LOC), mTBI with loss of consciousness; mTBI (AMS), mTBI with altered mental state; OR, odds ratio; PTSD, posttraumatic stress disorder.
[a]Adjusted for gender, age (in 5 groups), educational status (in 4 groups), and marital status (3 groups).
[b]in addtion, adjusted for service, rank, engagement status, deployed theatre, number of deployments, combat role, and time outside base in hostile area.

States and between 5.8 and 10.8 per 1000 for the United Kingdom between 2006 and 2009). If we combined fatalities in Iraq and Afghanistan, UK armed forces experienced lower fatality rates in 2005, but from 2006 to 2009, fatality rates have been similar. Overall, there is no compelling evidence to suggest that the observed differences are solely due to differences in combat exposure.

Another reason for the difference in prevalence could be related to cultural perspectives and health contexts in the 2 countries: differences in welfare provision, access to health services, and negative expectations and beliefs may impinge on the perception of symptoms and their interpretation between the United States and the United Kingdom.[1,4,24] While mTBI has been a major preoccupation in the United States, with a large budget devoted to assessment, management, and treatment, the response in the United Kingdom has been more muted.[25]

A more technical explanation is whether our study measured incidence rather than prevalence rates because the study assessed only mTBI in the last deployment. This cannot be the reason for the difference in relative frequency between studies because the same approach was followed in at least some of the US studies.[1,7]

Risk factors for, and associations with, mTBI

Having a combat role and spending longer outside base in a hostile area were the only deployment-related associations with mTBI. However, head injury is not the only problem to be expected in a combat situation; psychological injury, such as PTSD, is also a possibility. The PTSD was the most consistent factor associated with mTBI in our study, most previous studies, and a systematic review.[1,4,5,26] The context in which mTBI occurs is also central to the development of PTSD.[9] The same intense traumatic event may have caused both PTSD and mTBI,[1] but PTSD has been noted to occur more frequently in mTBI than in severe TBI.[27] It is worth noting that the 2 conditions may not only have a common etiology but also share several nonspecific symptoms.[1,4,11] However, there was evidence based on our longitudinal subsample that alcohol misuse, psychological distress, and, possibly, PTSD at phase 1 may have influenced later reporting of mTBI. Thus, prior mental disorders could be vulnerability factors for reporting mTBI symptoms as well as mTBI being associated with current PTSD possibly caused by the same injury event.

An association between MPS, excluding PCS, and mTBI has been previously reported.[1] In our study, we excluded PCS from the list of physical symptoms, thus ensuring that the association with mTBI was genuine and not merely double counting. Alcohol misuse at phase 1 and at phase 2 was associated with mTBI. As already discussed, these findings suggest that alcohol misuse is a potential vulnerability factor associated with mTBI reporting, which may operate directly or via shared factors

TABLE 5 *Unadjusted and adjusted association of mTBI, as independent factor, with each postconcussion symptom or multiple physical symptoms as dependent variables in the total sample (N varied between 584 and 682 participants because some participants did not complete all questions)*

	Unadjusted OR (95% CI)	Adjusted for sociodemographic and military variables,[a] AOR (95% CI)	Adjusted for all confounders,[b]) AOR (95% CI)	Adjusted for all confounders) and PTSD,[c] AOR (95% CI)	Adjusted for all confounders and PTSD, GHQ case, alcohol misuse, and MPS,[d] AOR (95% CI)
MPS case	2.41 (1.29–4.48)	2.84 (1.39–5.76)	2.59 (1.28–5.25)	1.85 (0.90–3.79)	n/a
Postconcussion symptom					
Headaches	1.66 (1.11–2.49)	1.82 (1.19–2.79)	2.25 (1.44–3.52)	2.03 (1.29–3.19)	1.64 (1.02–2.64)
Irritability/outbursts anger	1.55 (1.04–2.33)	1.80 (1.16–2.78)	1.98 (1.24–3.17)	1.71 (1.05–2.78)	1.57 (0.91–2.70)
Double vision	7.28 (2.85–18.64)	8.28 (3.36–20.39)	10.22 (3.94–26.52)	7.44 (2.88–19.24)	9.12 (3.06–27.20)
Forgetfulness	1.28 (0.84–1.95)	1.47 (0.94–2.32)	1.32 (0.83–2.11)	1.13 (0.69–1.86)	1.04 (0.59–1.81)
Dizziness	2.22 (1.30–3.81)	2.69 (1.50–4.83)	3.03 (1.66–5.55)	2.23 (1.20–4.15)	2.30 (1.09–4.86)
Loss of concentration	1.64 (1.08–2.48)	1.82 (1.17–2.82)	1.87 (1.20–2.93)	1.49 (0.93–2.40)	1.16 (0.65–2.07)
Ringing in ears	2.09 (1.35–3.24)	2.18 (1.40–3.40)	1.92 (1.21–3.04)	1.64 (1.03–2.62)	1.53 (0.93–2.53)
Fatigue	1.05 (0.70–1.57)	1.28 (0.84–1.96)	1.38 (0.89–2.15)	1.14 (0.72–1.81)	0.94 (0.55–1.62)
Sleeping difficulties	1.41 (0.93–2.15)	1.64 (1.06–2.54)	1.66 (1.05–2.62)	1.37 (0.85–2.20)	1.23 (0.71–2.13)

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; MPS, multiple physical symptoms; mTBI, mild traumatic brain injury; OR, odds ratio.

[a]Adjusted for gender, age (in 5 groups), educational status (in 4 groups), and marital status (3 groups), and service, rank, engagement status, deployed theatre, and number of deployments.

[b]Adjusted additionally for combat role and time outside base in hostile area.

[c]Adjusted additionally for PTSD at phase 2.

[d]Adjusted additionally for PTSD, alcohol misuse GHQ case, and MPS at phase 2.

such as personality variables or coping styles. Alcohol misuse has not been previously explored in relation to mTBI in the military. Alcohol is well known to be associated with head injury in civilian life, but the association in the military will be different, since the US and UK military personnel in both Iraq and Afghanistan are not allowed to drink alcohol during deployments. We did not find that general psychological distress, except in phase 1, was associated with mTBI.[1] Hoge and colleagues,[1] using the depression assessment module of the Patient Health Questionnaire, did find an association, possibly because their measure was more specific for the diagnosis of depression than the GHQ.

Postconcussion symptoms and mTBI

Our results suggesting an association between mTBI and subsequent PCS have some similarities and some differences to those reported by Hoge and colleagues.[1] In contrast to Hoge and colleagues,[1] we could not carry out the analyses separately for mTBI (LOC) due to the low prevalence of LOC in our study. Notwithstanding this difference, the unadjusted models of mTBI and physical symptoms in both studies showed that mTBI was associated both with PCS and with other physical symptoms unrelated to concussion. After adjustment for PTSD in our study, in contrast to Hoge and colleagues,[1] mTBI showed a consistent pattern of associations with most PCS. When we adjusted for alcohol misuse and MPS, only 3 of the 9 PCS remained significant. As alcohol misuse was not the factor that decreased the association between mTBI and PCS, the most likely explanation of our results is that personnel with mTBI have a tendency to endorse a greater number of symptoms than personnel with other injuries, as suggested in other studies.[28]

As in the US study,[1] mTBI remained significantly associated with headaches, regardless of the level of adjustment. Posttraumatic headache has been found to be a frequent symptom after head or neck injury, about 85% of which is of the tension type.[29] Although mTBI was not significantly associated with dizziness in the study of Hoge and colleagues,[1] the AOR in their study was high in the group of mTBI (LOC) (OR = 4.0) and mTBI (AMS) (OR = 2.15). We also found a strong association between mTBI and the reporting of double vision, which was not assessed in any of the US military studies.[1,4–7] The distribution of perception of severity of double vision into mild, intermediate, and severe was similar in those with mTBI and those with only other injury and was more common in the mTBI (AMS) group than in the mTBI (LOC) group. Double vision is infrequently endorsed (2.6%) in the total sample, while the percentage was 14.5% in the mTBI (AMS) group. We do not think that this association was confounded by anxiety leading to overreporting of non-mTBI visual disturbance, as we adjusted for all our psychological measures and the association persisted. One speculation is that such a specific symptom may be related to blast injury, which, while not necessarily causing severe brain damage or, indeed, PCS,[5] may lead to a combination of minor concussion plus ear-and-eye trauma.[30]

In our analysis, we followed the procedure of Hoge and colleagues,[1] who adjusted for PTSD, rather than the approach of Brenner and colleagues,[31] who estimated the possible joint effect of PTSD and mTBI on PCS, because our aim was to assess the independent effect of mTBI on PCS.

Although access to the British National Health Service (NHS) is free of cost to everybody, and a person who leaves the UK armed forces with a service-attributable diagnosis is entitled to priority treatment under the NHS, mTBI is hardly recognized and would not open the door to any specialist service in the United Kingdom. However, individuals who leave service with a diagnosis of PCS and have associated disability would be assessed for a war pension. In contrast, in the United States, veterans are entitled to only 5 years of Veteran's Affairs healthcare; thus, there may be an advantage to report PCS, even if borderline, as early as possible. The high profile of mTBI in the United States and the 2008 Federal regulations, which assigns a 40% disability to those who have 3 or more subjective symptoms that moderately interfere with functioning, may also play a role in reporting mTBI and PCS.[24] In summary, the differences in the approach to mTBI and PCS in the 2 countries may be related to access to healthcare (free in perpetuity) in the United Kingdom and cultural issues related to compensation and litigation.

Strengths and weaknesses

This is the first large study to assess mTBI in the UK armed forces. It has the advantage over other military studies in that a large subsample could be studied longitudinally to assess the contribution of preinjury psychiatric morbidity to the etiology of mTBI. The necessity to use 3, as opposed to 1, samples, forced on us because of the unanticipated prolongation of the Iraq campaign and the escalation of fighting in Afghanistan, both of which happened after our initial sample frame was selected, has added some complexity to the analysis. However, if we had restricted ourselves to a follow-up of only the original sample first reported in 2006,[12] this would have greatly underestimated personnel younger than 25 years who make up 8% of the officers and 33% of the other ranks in the UK armed forces. It would also have missed the majority of the UK deployment to Helmand province, Afghanistan. By adding the additional samples, we ensured that the study population

continued to reflect the demographic makeup of the current armed forces.[13]

Although the longitudinal design of the study helped to assess the contribution of psychiatric morbidity on mTBI, the study was cross-sectional regarding the assessment of the association between mTBI and PCS, a limitation for inferring causation. This is a common weakness with other military studies. Caution is recommended in the interpretation of differences in the prevalence of mTBI between the United Kingdom and the United States, as the length of deployment is shorter for the UK than for the US troops. Although questions about mTBI and symptoms of PCS were in separate sections of a long questionnaire, recall bias cannot be excluded as a possible contributory factor.[32] It is possible that some participants had forgotten prior events that memory has been influenced by current psychiatric state as time since injury increases. However, there was no difference in the prevalence of mTBI among those who indicated that their last deployment occurred before 2006 and those deployed more recently. Ideally, one would assess mTBI directly in theatre, but such studies are difficult to carry out. Most mTBI events happen in exposed combat situations, but only more severely injured personnel (ie, TBI and not mTBI) will be evacuated to a medical facility in which investigation and data collection are feasible. Although our study is not exempted from the criticism that subjects with mTBI tend to overreport PCS when completing questionnaires,[33] our study shares the same approach with the US population studies and the reported differences cannot be ascribed to this approach.

Implications and conclusions

Prior psychological distress, alcohol misuse, and, possibly, PTSD were vulnerability risk factors for subsequent reporting of mTBI, and mTBI is frequently accompanied by PTSD, MPS, and alcohol misuse. This study gives some support to the view that the sequelae of mTBI are related more to psychopathology than to neuropathology because of the lack of association between mTBI and subsequent PCS symptoms after appropriate adjustments for 6 of the 9 PCS symptoms. The exceptions were double vision and, to a lesser extent, headache and dizziness. Mild traumatic brain injury has previously been associated with headache,[1,34] and there are some indications of an association with dizziness,[1] a strong association with double vision has not been reported before.

Do our results have implications for treatment? Having learned that PCS owed more to psychological distress than to any putative damage to the central nervous system caused by proximity to the exploding shell,[3] British military doctors in both world wars argued that rather than becoming preoccupied with categorizing PCS into functional versus organic causes, the most important factor reducing invalidism was to promote the early expectation of recovery.[35] This approach has been echoed recently by the view that the most efficacious treatment of mTBI is education to provide expectations of a prompt recovery.[1] It is for that reason that there is a gradual emergence in the United States of a desire to move away from the label of mTBI, which emphasizes both brain and injury, and back to concussion,[24] a view that is supported by the results of this article.

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