Original Investigation | Neurology

Contrasting Characteristics and Outcomes of Sports-Related and Non–Sports-Related Traumatic Brain Injury

Michail Ntikas, PhD; William Stewart, MD; Magdalena Ietswaart, PhD; Angus M. Hunter, PhD; Andrew I. R. Maas, MD; David K. Menon, MD; Lindsay Wilson, PhD; for the CENTER-TBI participants and investigators

Abstract

IMPORTANCE Exposure to traumatic brain injury (TBI) has raised widespread concern over participation in sports, particularly over possible long-term consequences. However, little is known about the outcomes of individuals presenting to hospitals with sports-related TBI.

OBJECTIVE To compare the characteristics and outcomes of individuals presenting to hospitals with sports-related and non–sports-related TBI.

DESIGN, SETTING, AND PARTICIPANTS The CENTER-TBI (Collaborative European NeuroTrauma Effectiveness Research in TBI) observational cohort study was conducted at hospitals in 18 countries. The study enrolled 4509 patients who had TBI and had an indication for computed tomography (CT), of whom 4360 were 16 years or older. Outcomes were assessed at 3 and 6 months, and groups were compared using regression analyses adjusting for clinical and demographic differences. Data were collected between December 9, 2014, and December 17, 2017, and analyzed from August 2022 to March 2023.

EXPOSURE Sports-related and non–sports-related TBI with subgroups selected by severity of injury.

MAIN OUTCOMES AND MEASURES The main outcome was the Glasgow Outcome Scale–Extended (GOSE) at 6 months, with secondary outcomes covering postconcussion symptoms, health-related quality of life, and mental health.

RESULTS A total of 4360 patients were studied, including 256 (6%) with sports-related TBI (mean [SD] age, 38.9 [18.1] years; 161 [63%] male) and 4104 with non–sports-related TBI (mean [SD] age, 51.0 [20.2] years; 2773 [68%] male). Compared with patients with non–sports-related TBI, patients with sports-related TBI were younger, more likely to have tertiary education, more likely to be previously healthy, and less likely to have a major extracranial injury. After adjustment, the groups did not differ in incomplete recovery (GOSE scores <8) at 6 months (odds ratio [OR], 1.27; 95% CI, 0.90-1.78; P = .22 for all patients; OR, 1.20; 95% CI, 0.83-1.73; P = .34 for those with mild TBI; and OR, 1.19; 95% CI, 0.74-1.92; P = .65 for those with mild TBI and negative CT findings). At 6 months, there was incomplete recovery in 103 of 223 patients (46%) with outcomes in the sports-related TBI group, 65 of 168 (39%) in those with mild sports-related TBI, and 30 of 98 (31%) in those with mild sports-related TBI and negative CT findings. In contrast, at 6 months, the sports-related TBI group had lower prevalence of anxiety, depression, posttraumatic stress disorder, and postconcussion symptoms than the non–sports-related group.

CONCLUSIONS AND RELEVANCE In this cohort study of 4360 patients with TBI, functional limitations 6 months after injury were common after sports-related TBI, even mild sports-related TBI. Persisting impairment was evident in the sports-related TBI group despite better recovery compared

(continued)

Key Points

Question Do the outcomes of individuals presenting to hospitals with sports-related traumatic brain injury (TBI) differ from those with non–sports-related TBI?

Findings This cohort study found that after adjustment for clinical and background differences, individuals with sports-related TBI had better recovery at 6 months of symptoms, mental health, and health-related quality of life than those with non–sports-related TBI. However, there was no significant difference in functional outcomes, and even in individuals with mild sports-related TBI and negative imaging findings, 31% still had some degree of disability.

Meaning The findings highlight the need for effective clinical follow-up and support for patients who present to hospitals after sports-related TBI irrespective of severity of injury.

+ **Invited Commentary**

+ **Supplemental content**

Author affiliations and article information are listed at the end of this article.

Abstract (continued)

with non–sports-related TBI on measures of mental health and postconcussion symptoms. These findings caution against taking an overoptimistic view of outcomes after sports-related TBI, even if the initial injury appears mild.

Introduction

There is increasing attention on the potential brain health consequences of traumatic brain injury (TBI) and repetitive head impacts, in particular their association with increased risk of neurodegenerative disease.[1] Participation in sports is a common cause of TBI: sports are responsible for approximately 6% of emergency department attendances with TBI[2] and 20% or more of TBIs recorded in the community as a whole.[3] Exposure to TBI, both single and repeated, has raised widespread concern over participation in sports, particularly over possible long-term consequences.[4]

Historically, TBI research has often been performed within broad domains, including military or civilian studies, with the latter separated into study of sports-related injuries and hospital-based research that has included mixed etiologies. In this literature, mild sports-related TBI (SR-TBI) has a better prognosis than general mild TBI.[5,6] However, differences are present between the 2 populations that confound crude comparison: individuals with SR-TBI have lower risk factors for poor outcome than those with general TBI (eg, younger age, fewer preinjury health conditions, and less severe injuries).[6] Despite the extensive literature on both SR-TBI and general TBI in adults, there are few direct comparisons between sports-related and non–sports-related TBI (NSR-TBI). A recent review[7] identified only 1 study directly contrasting recovery after SR-TBI and NSR-TBI.[8] This study used the Rivermead Post-concussion Symptoms Questionnaire (RPQ) at 3 months and found no difference between groups. Therefore, there is a need for work in this area that addresses a range of outcomes and uses data collection over a longer timescale.

Individuals with mild TBI who present to hospitals are a particular concern because of evidence that they frequently experience long-term disability and persisting symptoms.[9-12] Approximately half report some limitations in function on the Glasgow Outcome Scale–Extended (GOSE) at 6 months after injury, even those with no abnormality on early computed tomography (CT).[10,13] A prospective study[14] found that most individuals with mild TBI or concussion associated with sports and recreation have good recovery from a clinical perspective. However, it has yet to be established whether persisting problems are observed in those who present to hospitals with sports-related injury.

Most hospital-based studies of TBI have not had sufficiently large samples to allow systematic comparisons between patients with different causes of injury. CENTER-TBI (Collaborative European NeuroTrauma Effectiveness Research in TBI) is a large-scale, prospective, longitudinal, observational project that enrolled patients with TBI from 18 countries.[15] Information is available in the data set concerning the injuries, background factors, clinical course, and outcomes, and this allows SR-TBI to be compared systematically with TBI from other causes. Accordingly, the aim of the study is to identify differences in the demographics and clinical characteristics of SR-TBI and NSR-TBI and compare outcomes up to 6 months after injury. In addition, we examined 2 subgroups created by applying further selection criteria: (1) patients with Glasgow Coma Scale (GCS) scores of 13 to 15 and (2) patients with GCS scores of 13 to 15 and negative CT results. These 2 subgroups represent types of injury of particular interest in the context of SR-TBI. Scores on the GCS of 13 to 15 are often used clinically to define mild TBI, and recent research using this definition had identified patients with persisting problems.[10,13] Scores on the GCS of 13 to 15 and negative CT results identify an even more mildly injured group, one that fulfills a widely used definition of concussion.[4]

Methods

The CENTER-TBI core study consists of 4509 patients with data collection between December 9, 2014, and December 17, 2017.[15] Data were analyzed from August 2022 to March 2023. Ethical approval was obtained for each center in accord with national and local requirements. Details of ethics approvals are on the project website.[16] Information about race and ethnicity was recorded by investigators at recruitment. We collected this information because it is relevant general background. This cohort study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline.

Participants

The criteria for inclusion in the CENTER-TBI project were presentation with TBI within 24 hours of injury, a clinical indication for CT, and availability of informed consent (written consent was obtained at the earliest opportunity, but some patients may have been enrolled initially with oral consent). Patients were excluded if they had a severe preexisting neurologic disorder that would interfere with outcome assessments. Recruitment was to 3 care pathways: emergency department (patients attending the emergency department and discharged), admission (patients admitted to hospital), and intensive care unit (patients admitted to the intensive care unit). For the current analyses, patients younger than 16 years were excluded: this was the age cutoff in the CENTER-TBI project for administering the full set of patient-reported outcomes. Patients were identified as having an SR-TBI if the place of injury was recorded as "sport/recreational" and the cause of injury was not a "road traffic accident" or "violence/attack." The participant selection process is shown in eFigure 1 in Supplement 1.

Measures

Demographic and clinical data were collected in the acute stage (**Table 1**). Preinjury physical health was assessed on the American Society of Anaesthesiologists Physical Status Classification System.[17] The presence of intracranial abnormalities was recorded from the first CT after injury.[18] Severity of injury was assessed by the GCS[19] and the Abbreviated Injury Scale.[20]

Outcomes

Follow-up for all patients was scheduled for 3 and 6 months either face-to-face or by postal questionnaire or telephone interview. The main outcome was global functional outcome at 6 months, with secondary outcomes covering postconcussion symptoms, health-related quality of life, and mental health.

Global Functional Outcome

The GOSE assesses global functional outcome in 8 categories: death, vegetative state, lower severe disability, upper severe disability, lower moderate disability, upper moderate disability, lower good recovery, and upper good recovery.[21] The GOSE was a composite of interviews and questionnaires that were scored centrally.[22] Because the vegetative state cannot be identified separately using a questionnaire, this category was combined with lower severe disability. Missing GOSE values were imputed using a multistate model when assessments were available at other time points up to 18 months after injury,[23] including 14% of 3-month and 16% of 6-month ratings. We used a cutoff value of lower good recovery or less (GOSE score <8) as an indication of incomplete recovery.

The 12-Item Short-Form Health Survey, version 2 (SF-12v2) assesses health-related quality of life.[24] Two scores were used: the physical component summary (PCS), which provides a measure of functional outcome, and the mental component summary (MCS), which assesses outcome related to aspects of mental health. Outcomes are expressed as T scores (mean [SD], 50 [10]) based on normative data from a 1998 US sample,[24] with higher scores indicating better quality of life. Scores range from 10 to 65 for the PCS and 8 to 72 for the MCS in the CENTER-TBI sample. T scores less than 40 on the PCS or MCS are considered to indicate significantly impaired health-related quality of life.[24]

Table 1. Demographic Characteristics of the Study Participants[a]

Characteristic	SR-TBI (n = 256)	NSR-TBI (n = 4104)
Age, mean (SD), y	38.9 (18.1)	51.0 (20.2)
Sex		
Female	95 (37)	1331 (32)
Male	161 (63)	2773 (68)
Race		
Asian	1 (0.4)	68 (2)
Black	1 (0.4)	61 (2)
White	245 (96)	3777 (92)
Unknown or missing	9 (4)	198 (5)
Highest level of education		
Primary	17 (8)	517 (16)
Secondary	72 (32)	1172 (37)
College or training	134 (60)	1520 (47)
Missing or unknown	33	895
Employment status		
Working (full or part time)	140 (59)	1806 (50)
Not working or homemaker	19 (8)	406 (11)
Retired	26 (10)	1086 (29)
Student	54 (23)	312 (9)
Missing	17	494
Care pathway		
Emergency department	77 (30)	765 (19)
Admission	86 (34)	1376 (34)
Intensive care unit	93 (36)	1963 (48)
Missing	0	0
ASA preinjury physical health		
Healthy	202 (80)	2156 (54)
Not healthy	51 (20)	1815 (46)
Missing	3	133
Preinjury neurologic condition		
Absent	244 (96)	3579 (90)
Present	10 (4)	390 (10)
Missing	2	135
Preinjury psychiatric condition		
Absent	238 (94)	3368 (85)
Present	16 (6)	581 (15)
Missing	2	155
Previous concussion		
Absent	215 (87)	3410 (91)
Present	31 (13)	360 (9)
Missing	10	334
GCS score at baseline		
3-8	34 (14)	928 (24)
9-12	16 (6)	355 (9)
13-14	35 (14)	650 (17)
15	162 (66)	2017 (51)
Missing	9	154
CT abnormality		
Absent	126 (52)	1458 (39)
Present	116 (48)	2248 (61)
Missing or uninterpretable	14	
Major extracranial injury[b]		
Absent	191 (75)	2636 (64)
Present	65 (25)	1468 (36)

Abbreviations: ASA, American Society of Anaesthesiologists; CT, computed tomography; GCS, Glasgow Coma Scale; NSR-TBI, non–sports-related TBI; SR-TBI, sports-related traumatic brain injury.

[a] Data are presented as number (percentage) of patients unless otherwise indicated.

[b] Any non–head and neck Abbreviated Injury Scale scores of 3 or higher (serious injury).

Mental Health

Symptoms of posttraumatic stress disorder (PTSD) were assessed with the PTSD Checklist for *DSM-5* (PCL-5).[25] The questionnaire includes 20 symptoms of PTSD based on the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition*.[26] Scores range from 0 to 80, with higher values indicating greater distress. We used a cutoff value of 33 or more as indicating probable PTSD.[27]

The Patient Health Questionnaire (PHQ-9) assesses 9 symptoms of depression.[28] Total scores range from 0 to 27, with higher values indicating greater emotional distress. A clinical cutoff value of 10 or more was taken to indicate probable depression.[28]

The Generalized Anxiety Disorder–7 (GAD-7) assesses 7 anxiety symptoms.[29] The total score ranges from 0 to 21, with greater values indicating greater emotional distress. A clinical cutoff value of 8 or more was applied to indicate probable anxiety disorder.[30]

Postconcussion Symptoms

The RPQ consists of 16 symptoms commonly reported after mild TBI or concussion.[31] Total scores range from 0 to 64, with higher scores indicating more severe symptoms. We used a cutoff value of 16 or greater as indicative of clinically significant postconcussion symptoms.[32]

Statistical Analysis

To ascertain whether background and clinical variables were independently associated with SR-TBI, we performed binary logistic regression with SR-TBI group membership as the dependent variable and demographic, socioeconomic, and clinical factors as independent variables. When comparing outcomes between patients with SR-TBI and NSR-TBI, we considered first the whole sample and then each of the 2 progressively less injured subsamples. All available data at each time point were used for the primary analyses. The denominator used for calculating percentages of impairment was the number of available outcomes for the assessment. In a supplementary sensitivity analysis, we included only patients with outcomes at both 3 and 6 months. Binary logistic regressions were performed with each of the dichotomized outcome measures. Covariates included were age, sex, highest level of education, preinjury employment status, TBI severity, CT abnormality, major extracranial injury, American Society of Anaesthesiologists Physical Status class, neurologic medical history, psychiatric medical history, and history of concussion (details on covariate levels can be found in Table 1). For missing data on covariates, we used multiple imputation with multivariate imputation by chained equations[33] in R statistical software.[34] The number of imputations was 10, and the maximum number of iterations was 5. We controlled for multiple comparisons among the 14 outcome measures by adjusting for the false discovery rate (FDR) using the sequential Bonferroni type procedure as described by Benjamini and Hochberg.[35] Statistical significance was set at a 2-sided $P < .05$, and analyses were conducted using R, version 4.0.4[34] and RStudio, version 1.4.1106 (R Project for Statistical Computing).[36]

Results

A total of 4360 patients were studied, including 256 (6%) with SR-TBI (mean [SD] age, 38.9 [18.1] years; 161 [63%] male; 1 [0.4%] Asian, 1 [0.4%] Black, 245 [96%] White, and 9 [4%] with unknown or missing race) and 4104 with NSR-TBI (mean [SD] age, 51.0 [20.2] years; 2773 [68%] male; 68 [2%] Asian, 61 [2%] Black, 3777 [92%] White, and 198 [5%] with unknown or missing race). Characteristics of the SR-TBI and NSR-TBI groups are given in Table 1 and the distribution of types of sports in **Table 2**. Patients with SR-TBI predominantly had mild injuries (162 of 247 [66%] had a GCS of 15) and were younger. The most common setting of SR-TBI was horseback riding (n = 57), followed by skiing (n = 44) and association football (soccer; n = 33).

Factors Associated With SR-TBI

Odds ratios (ORs) for multivariate comparisons of background and clinical characteristics of SR-TBI and NSR-TBI are shown in **Figure 1**. Patients with SR-TBI were significantly younger (OR, 0.98; 95% CI, 0.97-0.99; *P* < .001); they were 2.12 (95% CI, 1.19-3.79) times more likely to have a university or college degree (*P* = .02) and were 2.38 (95% CI, 1.42-4.00) times more likely to be classified as healthy before their injury (*P* = .001). They were also 1.59 (95% CI, 1.09-2.31) times less likely to have a major extracranial injury (*P* = .02).

Outcome Measures

Figure 2 summarizes our main findings as percentages of impairment in the SR-TBI and NSR-TBI groups, whereas **Figure 3**A, B, and C provides the results of adjusted comparisons using regression

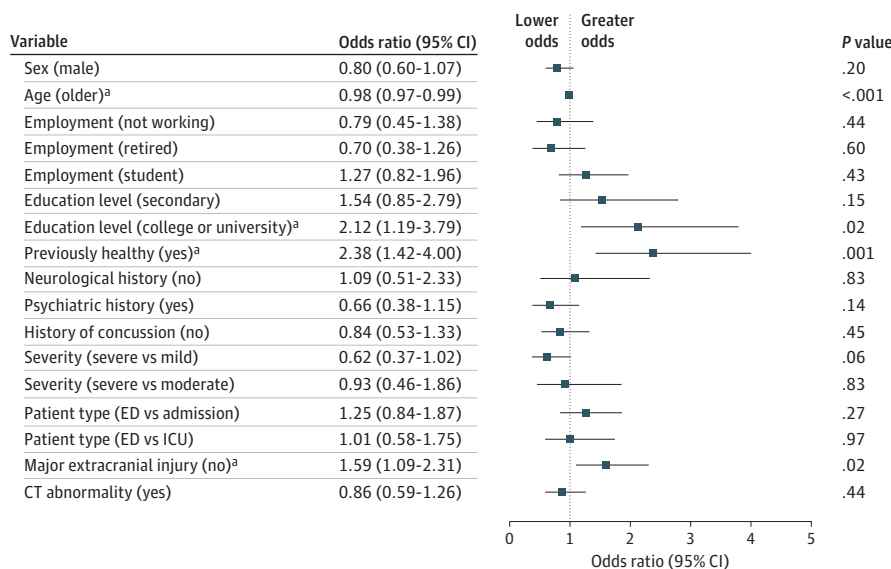**Table 2. Characteristics of SR-TBI per Type of Sport**

Sport	SR-TBI cases, No. (%) (n = 256)	Sex, No. (%)		Age, mean (SD), y	SR-TBI severity, No. (%)		
		Male	Female		Mild	Moderate	Severe
Team sports							
Association football	33 (13)	31 (94)	2 (6)	25 (9)	29 (88)	4 (12)	0
Rugby	8 (3)	5 (63)	3 (37)	23.5 (7)	8 (100)	0	0
Hockey (ice or field)	6 (2)	4 (67)	2 (33)	29 (10)	5 (83)	1 (17)	0
Other	17 (7)	10 (41)	7 (59)	26 (13)	16 (94)	1 (6)	0
Total	64	50 (78)	14 (22)	25 (10)	58 (91)	6 (9)	0
Individual sports							
Horseback riding	57 (22)	6 (11)	51 (89)	42.5 (17)	42 (74)	5 (9)	6 (11)
Skiing	44 (17)	36 (82)	8 (18)	43.5 (19)	30 (68)	4 (9)	9 (20)
Cycling[a]	23 (9)	18 (78)	5 (22)	45.5 (19)	21 (92)	0	2 (9)
Off-road vehicular sports	7 (3)	7 (100)	0	42.5 (27)	5 (71)	0	2 (29)
Rollerblading, scooter, skateboarding	5 (2)	4 (80)	1 (20)	35 (11)	5 (100)	0	0
Other	51 (20)	36 (71)	15 (29)	46 (19)	33 (65)	1 (2)	14 (27)
Total	187	107	80	43 (18)	136	10	37

Abbreviation: SR-TBI, sports-related traumatic brain injury.

[a] In cycling, 37 cases were identified as sports or recreational, but 14 of them were excluded due to also being described as "road traffic accidents," leaving 23 cases with SR-TBI caused by cycling. In the database, cyclists represented 563 (34.7%) of 1624 road traffic incidents.

Figure 1. Multivariate Association of Background and Clinical Variables With Cause of Injury

Variable	Odds ratio (95% CI)	P value
Sex (male)	0.80 (0.60-1.07)	.20
Age (older)[a]	0.98 (0.97-0.99)	<.001
Employment (not working)	0.79 (0.45-1.38)	.44
Employment (retired)	0.70 (0.38-1.26)	.60
Employment (student)	1.27 (0.82-1.96)	.43
Education level (secondary)	1.54 (0.85-2.79)	.15
Education level (college or university)[a]	2.12 (1.19-3.79)	.02
Previously healthy (yes)[a]	2.38 (1.42-4.00)	.001
Neurological history (no)	1.09 (0.51-2.33)	.83
Psychiatric history (yes)	0.66 (0.38-1.15)	.14
History of concussion (no)	0.84 (0.53-1.33)	.45
Severity (severe vs mild)	0.62 (0.37-1.02)	.06
Severity (severe vs moderate)	0.93 (0.46-1.86)	.83
Patient type (ED vs admission)	1.25 (0.84-1.87)	.27
Patient type (ED vs ICU)	1.01 (0.58-1.75)	.97
Major extracranial injury (no)[a]	1.59 (1.09-2.31)	.02
CT abnormality (yes)	0.86 (0.59-1.26)	.44

Odds ratios are given for membership of the sports-related traumatic brain injury group. Error bars indicate 95% CIs. CT indicates computed tomography; ED, emergency department; and ICU, intensive care unit.

[a] Significant at *P* < .05 level.

analyses. Completion rates for outcomes are provided in eTable 1 in Supplement 1 and percentages impaired on each assessment in eTable 2 in Supplement 1. The application of FDR correction to probabilities is detailed in eTable 3 in Supplement 1.

Three-Month Outcomes

The GOSE was the outcome with the greatest percentage of impairment in both the SR-TBI and NSR-TBI groups (Figure 2; eTable 2 in Supplement 1): 115 of 222 patients (52%) with outcomes in the SR-TBI group and 2390 of 3428 patients (70%) with in the NSR-TBI group had GOSE scores less than 8. The difference on the GOSE did not reach significance after correction (OR, 1.40; 95% CI, 1.00-1.96; P = .07). On the patient-reported outcomes, patients with SR-TBI were significantly less impaired than the NSR-TBI group on the PCS, GAD-7, and PCL-5 but not on the MCS, RPQ, and PHQ-9 (Figure 3A). In the SR-TBI group, impaired scores were relatively common on the PCS (36 [22%]), MCS (38 [23%]), and RPQ (35 [22%]), indicating that TBI symptoms and problems related to physical and mental health remained prominent at this time point, whereas clinically significant levels of depression (PHQ-9; 20 [13%]), anxiety (GAD-7; 11 [7%]), and PTSD (PCL-5; 5 [3%]) were relatively low.

Analysis of subgroups with milder injuries showed that a GOSE score less than 8 was present in 70 of 168 patients (42%) with mild SR-TBI and in 32 of 98 patients (33%) with mild SR-TBI and

Figure 2. Percentages of Impaired Outcomes at 3 and 6 Months for Sports-Related and Non–Sports-Related Traumatic Brain Injury (TBI) in 3 Severity Groups (All Severities of Injury, Mild TBI, and Mild TBI With Negative Computed Tomography [CT] Results)
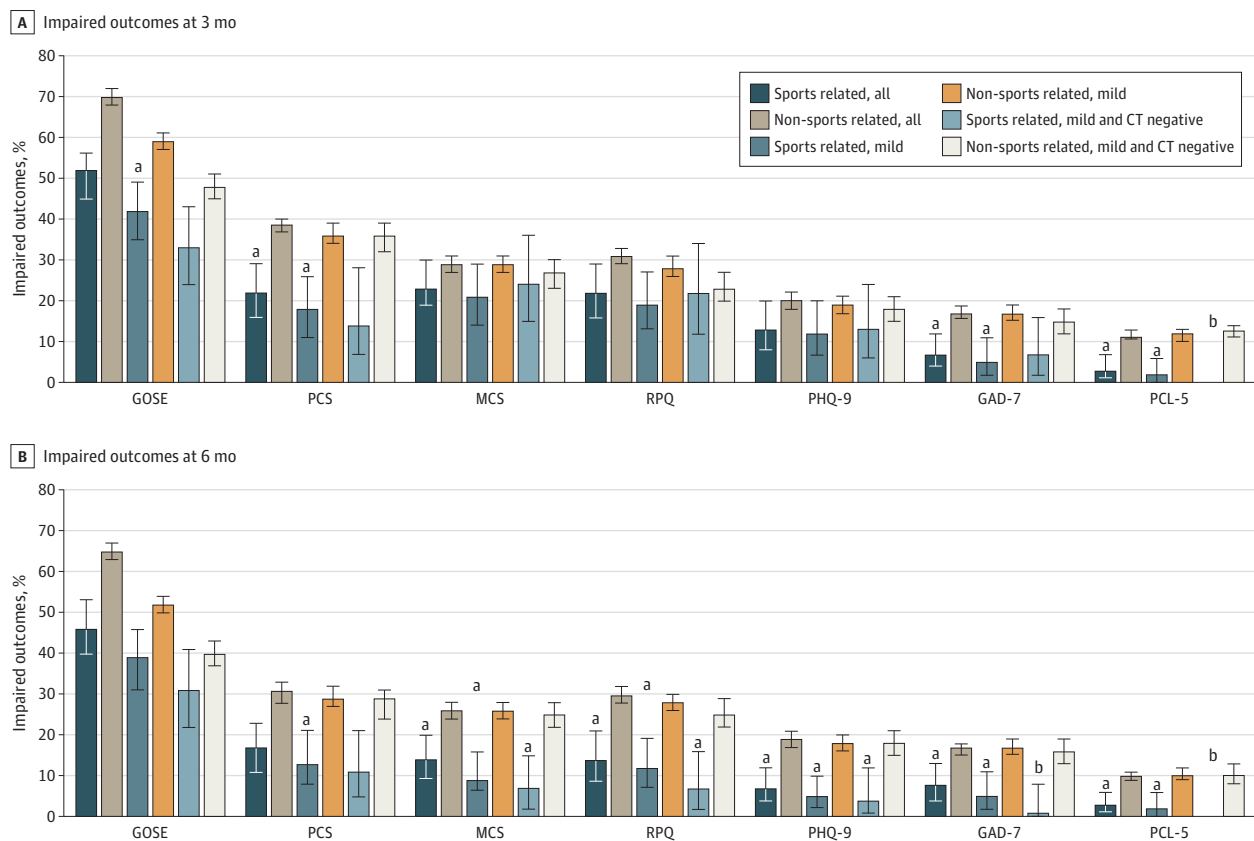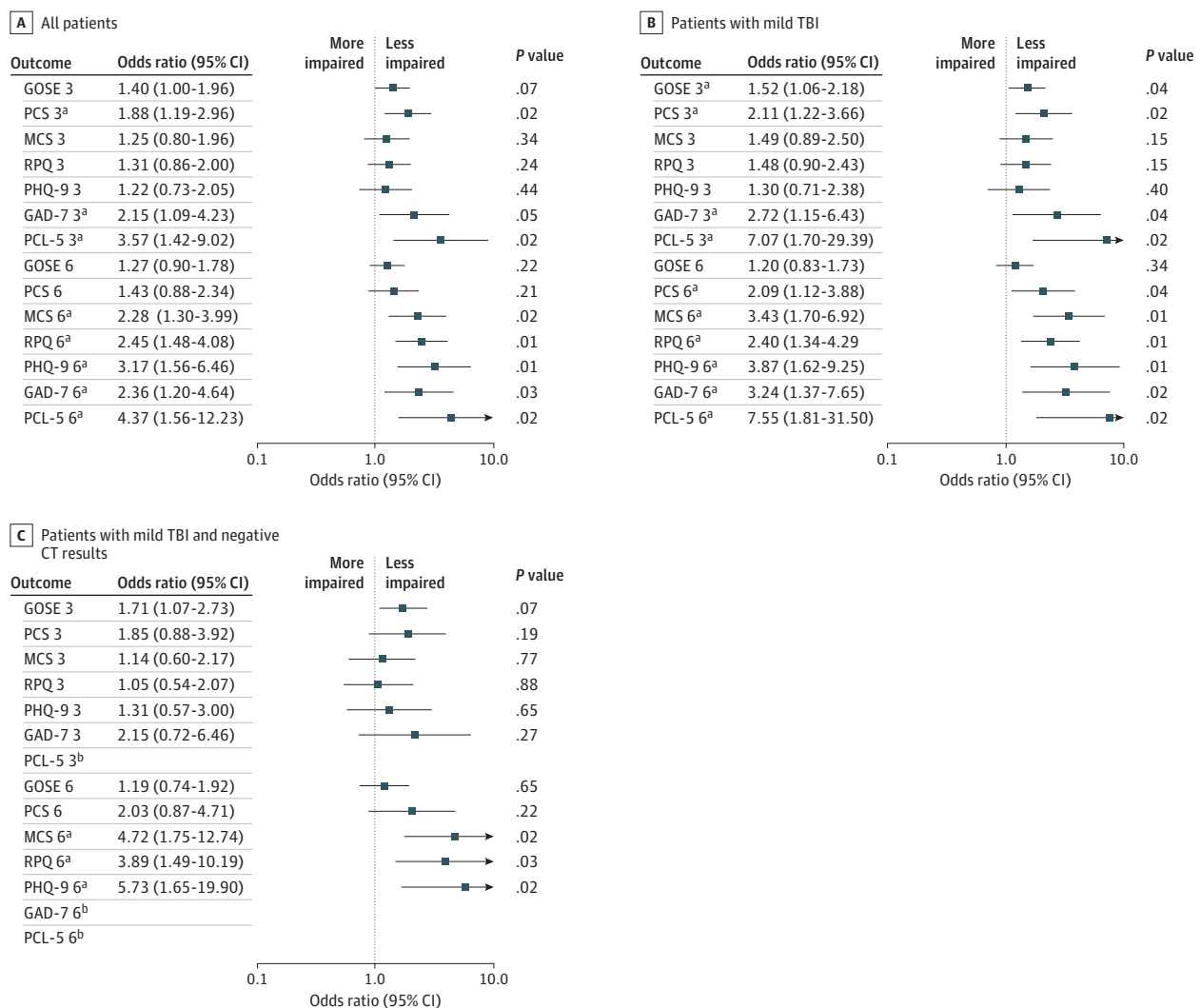

GAD-7, Generalized Anxiety Disorder-7; GOSE, Glasgow Outcome Score–Extended; MCS, mental component summary; PCL-5, Posttraumatic Stress Disorder Checklist for *DSM-5*; PCS, physical component summary; PHQ-9, Patient Health Questionnaire–9; RPQ, Rivermead Post-concussion Symptoms Questionnaire. Error bars indicate 95 CIs.

[a] Significant at the P < .05 level after adjustment for covariates and false discovery rate correction. The bars are paired, and the comparison is between the sports-related TBI bar indicated and the corresponding non–sports-related TBI bar immediately to the right.

[b] Too few positive cases for analysis.

negative initial CT results compared with 1289 of 2202 (59%) and 524 of 1094 (48%), respectively, in the corresponding NSR-TBI groups. The difference between groups was significant for mild TBI (OR, 1.52; 95% CI, 1.06-2.18; *P* = .04) but not for mild TBI with negative CT results (OR, 1.71; 95% CI, 1.07-2.73; *P* = .07). Patients with mild SR-TBI were significantly less impaired than the NSR-TBI group on the PCS, GAD-7, and PCL-5 (Figure 3B), whereas there were no significant outcome differences between groups with mild SR-TBI and negative CT results (Figure 3C). Patterns of impaired scores in these less severely injured patients were similar to the group as a whole, and impaired scores were relatively common on the MCS (mild TBI: 17 [21%]; mild TBI with negative CT results: 17 [24%]) and RPQ (mild TBI: 23 [19%]; mild TBI with negative CT results: 14 [22%]).

Figure 3. Odds Ratios for Comparison of Sports-Related Traumatic Brain Injury (TBI) vs Non–Sports-Related TBI on Outcomes at 3 and 6 Months, After Injury Adjusting for Covariates

Larger odds ratios indicate better outcomes in the sports-related TBI group. *P* values are corrected for a false discovery rate of 5%. Error bars indicate 95% CIs. CT indicates computed tomography; GAD-7, Generalized Anxiety Disorder–7; GOSE, Glasgow Outcome Score–Extended; MCS, mental component summary; PCL-5, Posttraumatic Stress Disorder Checklist for *DSM-5*; PCS, physical component summary; PHQ-9, Patient Health Questionnaire–9; RPQ, Rivermead Post-concussion Symptoms Questionnaire.

[a] Significant at the *P* < .05 level after adjustment for covariates and false discovery rate correction.

[b] Too few positive cases for analysis.

Six-Month Outcomes

At the 6-month follow-up, the percentage of patients with GOSE scores less than 8 was still elevated: 103 of 223 patients (46%) with outcomes in the SR-TBI group had incomplete recovery (GOSE scores <8) compared with 2233 of 3451 patients (65%) in the NSR-TBI group (Figure 2). The difference between groups was not significant after adjustment (OR, 1.27; 95% CI, 0.90-1.78; P = .22). On the patient-reported outcomes, patients with SR-TBI were significantly less impaired than the NSR-TBI group on all assessments except the PCS (Figure 3A).

Analysis of subgroups with milder injuries showed that the number with GOSE scores less than 8 remained high at 6 months: 65 of 168 patients (39%) with mild SR-TBI and 30 of 98 (31%) with mild SR-TBI and negative CT results compared with 1146 of 2212 (52%) and 437 of 1095 (40%), respectively, in the corresponding NSR-TBI groups. The difference between groups on the GOSE was not significant for mild TBI (OR, 1.20; 95% CI, 0.83-1.73; P = .34) or mild TBI with negative CT results (OR, 1.19; 95% CI, 0.74-1.92; P = .65) (Figure 3B and C). However, patients with mild SR-TBI were significantly less impaired than the NSR-TBI group on all patient-reported outcomes (Figure 3B). Patients with mild SR-TBI and negative CT results were significantly less impaired on the MCS, RPQ, and PHQ-9, and low absolute numbers of impaired individuals precluded formal comparisons on the GAD-7 and PCL-5 (Figure 3C). Thus, although functional recovery on the GOSE remains incomplete at 6 months, TBI symptoms and problems related to mental health are consistently less frequent in the SR-TBI subgroups than the NSR-TBI subgroups.

Sensitivity Analysis

In a sensitivity analysis, we included all patients with outcome measures at both 3 and 6 months (eResults in Supplement 1). Findings for this analysis were similar to those using all cases, and the 95% CIs at 3 and 6 months overlapped for all measures (eFigure 2 in Supplement 1).

Discussion

The findings of this cohort study confirm the presence of systematic background and clinical differences between groups with SR- and NSR-TBI. Patients with SR-TBI were younger, were more likely to be college students, and reported better health before injury than patients with NSR-TBI. In addition, SR-TBI was less likely to be accompanied by major extracranial injury. These differences are consistent with characteristics described previously.[6] The current analysis demonstrates that differences are independently associated with SR-TBI and indicates that individuals with sports-related injuries represent a selective subsample of individuals with TBI.

After considering potential risk factors, the level of functional recovery on the GOSE in SR-TBI and NSR-TBI at 3 months was only significantly different in the subgroup with mild TBI, whereas at 6 months none of the comparisons remained significant. More than half (52%) of patients with SR-TBI had an incomplete recovery on the GOSE 3 months after the TBI, whereas nearly half (46%) were still not fully recovered at 6 months. Even in patients with an SR-TBI who incurred injuries that would be considered mild, this proportion was still high (39%) 6 months after injury. The finding that SR-TBI, including mild SR-TBI, was associated with persisting disability is consistent with recent findings from hospital-based studies of TBI, showing that injuries categorized as mild often have long-term consequences.[9]

At 3 months after injury, the SR-TBI group had fewer impaired outcomes on scales assessing anxiety and PTSD than those with NSR-TBI. On the other hand, impairment on the SF-12v2 MCS and the PHQ-9 was common in both groups. By 6 months, the SR-TBI group showed better recovery across all measures of mental health than the NSR-TBI group. The findings thus suggest that in the SR-TBI group, there is relative resistance to initial anxiety and stress and better long-term recovery from other mental health problems than in those with NSR-TBI. This finding is consistent with other reports, including, for example, the low observed prevalence of mental health problems in former professional soccer players.[37] The proportion of patients with persistent postconcussion symptoms

at 3 months is higher than generally described for college athletes,[38] but the prevalence of symptoms diminishes by 6 months in parallel with the decrease in general mental health problems.

We found higher prevalence of impairment on the GOSE than the RPQ, which is consistent with a previous hospital-based study of mild TBI.[9] Impairment on the RPQ was common at 3 months but had decreased substantially by 6 months. Historically, assessment of outcome after mild TBI, and specifically mild SR-TBI, has used scales such as the RPQ or similar symptom checklists. The presence of discrepancies among instruments indicates the desirability of a multidimensional approach to assessing outcomes after mild TBI to capture the full range of symptoms and problems that are present.

The CENTER-TBI cohort consists of patients who attended specialized neuroscience centers (equivalent to level I trauma centers in the US) who were triaged to receive CT. There are several hundred such specialized centers across Europe and the US; the findings are thus of direct relevance to a large group of patients but cannot be extrapolated to patients with SR-TBI who do not present at hospitals. The subgroup with GCS scores of 13 to 15 and negative CT findings are closest to having a sports concussion but nonetheless may well have sustained more significant injuries than a typical head injury sustained in sports. We used GCS scores of 13 to 15 to identify mild TBI because this definition is widely recognized in acute care and influences initial management. Other approaches, such as the American Congress of Rehabilitation Medicine criteria,[39] would limit the number of cases considered to be mild. On the other hand, 80% of the SR-TBI sample had a GCS score of 13 to 15 and 66% had a GCS score of 15. Furthermore, advantages of this cohort study are its sampling technique, sample size, the range of sports activities represented, and the ability to control for confounding variables.

The outcome differences between groups suggest that there may be influences that were not controlled for in the analyses. For example, individuals who present to hospitals after sports injuries may have milder types of TBI that are not captured by the measures of severity used in this study. Athletes may receive superior postinjury support from sporting colleagues familiar with concussion. Light controlled exercise the first week after mild TBI can have positive effects on patients' mental health and is beneficial for recovery.[40,41] Patients with SR-TBI are presumably more likely to engage in exercise in the weeks after TBI than other patients due to their desire to return to sports. Individuals with SR-TBI have greater resilience to some of the consequences of TBI, in keeping with a benign view of the effects of concussion in sports. However, the presence of persisting limitations of functional outcome specifically warns against assuming an overoptimistic view of outcomes of mild SR-TBI. The fact that this group includes individuals who are relatively young and generally healthy before injury makes the presence of persisting problems particularly salient.

Limitations

This study has some limitations. The study is based on patients triaged to CT attending specialist centers, and it is important to establish the extent of generalizability to other SR-TBI contexts. Furthermore, there was an absence of detailed records of preinjury problems and lack of information about treatment and support received after injury, which limits the explanations that can be offered for differences in outcome. Most cycling injuries recorded in the database were incurred in road traffic incidents, and we could not robustly identify those that involved a primary purpose for sports activity vs cycling as a mode of transport. As a result, most cycling injuries were considered transport related and included in the NSR-TBI group. A future study should explore this important cause of TBI. The CENTER-TBI study did not recruit an NSR-TBI control group, and although there are established cutoffs for outcomes, controls with extracranial injuries would potentially have allowed the specific influence of TBI to be better evaluated. Loss to follow-up is an issue and may bias findings toward a more pessimistic view of outcome, particularly in mild TBI.[9] We addressed this problem for the GOSE using single imputation of missing values, but there were still gaps in the data. A number of important issues remain for future study. There is a need for work investigating the kinds of functional problems that individuals experience in the long term and the specific symptoms or domains that are driving

differences in outcome. The effects of prior concussion and differences between types of sport and level of engagement (amateur vs professional) are also important issues for future research.

Conclusions

In this cohort study, the sample with SR-TBI differed from the NSR-TBI group and was characterized by having lower risk factors for poor outcome. Six months after SR-TBI, recovery of mental health and postconcussion symptoms were better than in the NSR-TBI group, even after considering risk factors in the group. However, in contrast to the idea that recovery after mild TBI or concussion is unproblematic, we found that approximately one-third of individuals with SR-TBI with GCS scores of 13 to 15 and negative CT results had persisting disability at 6 months. The findings have implications for injury prevention and management and indicate that even among individuals with sports injuries considered to be mild, many would benefit from systematic follow-up.

REFERENCES

1. Wilson L, Stewart W, Dams-O'Connor K, et al. The chronic and evolving neurological consequences of traumatic brain injury. *Lancet Neurol*. 2017;16(10):813-825. doi:10.1016/S1474-4422(17)30279-X

2. Selassie AW, Wilson DA, Pickelsimer EE, Voronca DC, Williams NR, Edwards JC. Incidence of sport-related traumatic brain injury and risk factors of severity: a population-based epidemiologic study. *Ann Epidemiol*. 2013;23 (12):750-756. doi:10.1016/j.annepidem.2013.07.022

3. Theadom A, Starkey NJ, Dowell T, et al; BIONIC Research Group. Sports-related brain injury in the general population: an epidemiological study. *J Sci Med Sport*. 2014;17(6):591-596. doi:10.1016/j.jsams.2014.02.001

4. Patricios JS, Schneider KJ, Dvorak J, et al. Consensus statement on concussion in sport: the 6th International Conference on Concussion in Sport-Amsterdam, October 2022. *Br J Sports Med*. 2023;57(11):695-711. doi:10.1136/bjsports-2023-106898

5. Karr JE, Areshenkoff CN, Garcia-Barrera MA. The neuropsychological outcomes of concussion: a systematic review of meta-analyses on the cognitive sequelae of mild traumatic brain injury. *Neuropsychology*. 2014;28(3): 321-336. doi:10.1037/neu0000037

6. Rabinowitz AR, Li X, Levin HS. Sport and nonsport etiologies of mild traumatic brain injury: similarities and differences. *Annu Rev Psychol*. 2014;65:301-331. doi:10.1146/annurev-psych-010213-115103

7. Brady M, Hume PA, Mahon S, Theadom A. What Is the evidence on natural recovery over the year following sports-related and non-sports-related mild traumatic brain injury: a scoping review. *Front Neurol*. 2022;12: 756700. doi:10.3389/fneur.2021.756700

8. Beauchamp F, Boucher V, Neveu X, et al. Post-concussion symptoms in sports-related mild traumatic brain injury compared to non-sports-related mild traumatic brain injury. *CJEM*. 2021;23(2):223-231. doi:10.1007/s43678-020-00060-0

9. Cancelliere C, Verville L, Stubbs JL, et al. Post-concussion symptoms and disability in adults with mild traumatic brain injury: a systematic review and meta-analysis. *J Neurotrauma*. 2023;40(11-12):1045-1059. doi:10.1089/neu.2022.0185

10. Nelson LD, Temkin NR, Dikmen S, et al; and the TRACK-TBI Investigators. Recovery after mild traumatic brain injury in patients presenting to US level I trauma centers: a Transforming Research and Clinical Knowledge in Traumatic Brain Injury (TRACK-TBI) study. *JAMA Neurol*. 2019;76(9):1049-1059. doi:10.1001/jamaneurol.2019.1313

11. Machamer J, Temkin N, Dikmen S, et al; TRACK-TBI Investigators. Symptom frequency and persistence in the first year after traumatic brain injury: a TRACK-TBI study. *J Neurotrauma*. 2022;39(5-6):358-370. doi:10.1089/neu.2021.0348

12. Mikolić A, Polinder S, Steyerberg EW, et al; Collaborative European NeuroTrauma Effectiveness Research in Traumatic Brain Injury (CENTER-TBI) Study Participants and Investigators. Prediction of global functional outcome and post-concussive symptoms after mild traumatic brain injury: external validation of prognostic models in the Collaborative European NeuroTrauma Effectiveness Research in Traumatic Brain Injury (CENTER-TBI) study. *J Neurotrauma*. 2021;38(2):196-209. doi:10.1089/neu.2020.7074

13. Woodrow RE, Winzeck S, Luppi AI, et al; CENTER-TBI MRI Substudy Participants and Investigators. Acute thalamic connectivity precedes chronic post-concussive symptoms in mild traumatic brain injury. *Brain*. 2023;146 (8):3484-3499. doi:10.1093/brain/awad056

14. Iverson GL, Gardner AJ, Terry DP, et al. Predictors of clinical recovery from concussion: a systematic review. *Br J Sports Med*. 2017;51(12):941-948. doi:10.1136/bjsports-2017-097729

15. Steyerberg EW, Wiegers E, Sewalt C, et al; CENTER-TBI Participants and Investigators. Case-mix, care pathways, and outcomes in patients with traumatic brain injury in CENTER-TBI: a European prospective, multicentre, longitudinal, cohort study. *Lancet Neurol*. 2019;18(10):923-934. doi:10.1016/S1474-4422(19)30232-7

16. CENTER-TBI. Ethical approval. Accessed December 15, 2023. https://www.center-tbi.eu/project/ethical-approval

17. Mayhew D, Mendonca V, Murthy BVS. A review of ASA physical status—historical perspectives and modern developments. *Anaesthesia*. 2019;74(3):373-379. doi:10.1111/anae.14569

18. Vande Vyvere T, De La Rosa E, Wilms G, et al; CENTER-TBI Participants and Investigators. Prognostic validation of the NINDS Common Data Elements for the radiologic reporting of acute traumatic brain injuries: a CENTER-TBI study. *J Neurotrauma*. 2020;37(11):1269-1282. doi:10.1089/neu.2019.6710

19. Teasdale G, Jennett B. Assessment of coma and impaired consciousness: a practical scale. *Lancet*. 1974;2 (7872):81-84. doi:10.1016/S0140-6736(74)91639-0

20. Baker SP, O'Neill B, Haddon W Jr, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma*. 1974;14(3):187-196. doi:10.1097/00005373-197403000-00001

21. Wilson JTL, Pettigrew LEL, Teasdale GM. Structured interviews for the Glasgow Outcome Scale and the extended Glasgow Outcome Scale: guidelines for their use. *J Neurotrauma*. 1998;15(8):573-585. doi:10.1089/neu.1998.15.573

22. Horton L, Rhodes J, Menon DK, Maas AIR, Wilson L; Collaborative European NeuroTrauma Effectiveness Research in TBI (CENTER-TBI) Participants and Investigators. Questionnaires vs interviews for the assessment of global functional outcomes after traumatic brain injury. *JAMA Netw Open*. 2021;4(11):e2134121. doi:10.1001/jamanetworkopen.2021.34121

23. Kunzmann K, Wernisch L, Richardson S, et al. Imputation of ordinal outcomes: a comparison of approaches in traumatic brain injury. *J Neurotrauma*. 2021;38(4):455-463. doi:10.1089/neu.2019.6858

24. Ware JE, Kosinski M, Turner-Bowker DM, Sundaram M, Gandek B, Maruish ME. *User's Manual for the SF-12v2 Health Survey*. 2nd ed. QualityMetric Inc; 2009.

25. Blevins CA, Weathers FW, Davis MT, Witte TK, Domino JL. The Posttraumatic Stress Disorder Checklist for DSM-5 (PCL-5): development and initial psychometric evaluation. *J Trauma Stress*. 2015;28(6):489-498. doi:10.1002/jts.22059

26. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders*. 5th ed. American Psychiatric Association; 2013.

27. Stein MB, Jain S, Giacino JT, et al; TRACK-TBI Investigators. Risk of posttraumatic stress disorder and major depression in civilian patients after mild traumatic brain injury: a TRACK-TBI Study. *JAMA Psychiatry*. 2019;76(3):249-258. doi:10.1001/jamapsychiatry.2018.4288

28. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. *J Gen Intern Med*. 2001;16(9):606-613. doi:10.1046/j.1525-1497.2001.016009606.x

29. Spitzer RL, Kroenke K, Williams JB, Löwe B. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Arch Intern Med*. 2006;166(10):1092-1097. doi:10.1001/archinte.166.10.1092

30. Kroenke K, Spitzer RL, Williams JB, Monahan PO, Löwe B. Anxiety disorders in primary care: prevalence, impairment, comorbidity, and detection. *Ann Intern Med*. 2007;146(5):317-325. doi:10.7326/0003-4819-146-5-200703060-00004

31. King NS, Crawford S, Wenden FJ, Moss NEG, Wade DT. The Rivermead Post Concussion Symptoms Questionnaire: a measure of symptoms commonly experienced after head injury and its reliability. *J Neurol*. 1995; 242(9):587-592. doi:10.1007/BF00868811

32. Thompson C, Davies P, Herrmann L, Summers M, Potter S. Approaches to establishing validated cut-off scores on the Rivermead Post Concussion Symptoms Questionnaire (RPQ) [abstract]. *Brain Injury*. 2016;30:770.

33. van Buuren S, Groothuis-Oudshoorn K. mice: Multivariate imputation by chained equations in R. *J Stat Softw*. 2011;45:1-67. doi:10.18637/jss.v045.i03

34. R Core Team. R: A language and environment for statistical computing. Accessed April 2, 2022. https://www.R-project.org/

35. Benjamini Y, Hochberg Y. Controlling the false discovery rate: a practical and powerful approach to multiple testing. *J R Stat Soc B*. 1995;57:289-300. doi:10.1111/j.2517-6161.1995.tb02031.x

36. R Studio Team. RStudio: integrated development environment for R. Accessed April 2, 2022. https://www.rstudio.com/

37. Russell ER, McCabe T, Mackay DF, et al. Mental health and suicide in former professional soccer players. *J Neurol Neurosurg Psychiatry*. 2020;91(12):1256-1260. doi:10.1136/jnnp-2020-323315

38. McCrea M, Guskiewicz K, Randolph C, et al. Incidence, clinical course, and predictors of prolonged recovery time following sport-related concussion in high school and college athletes. *J Int Neuropsychol Soc*. 2013;19 (1):22-33. doi:10.1017/S1355617712000872

39. Silverberg ND, Iverson GL; ACRM Mild TBI Definition Expert Consensus Group and the ACRM Brain Injury Special Interest Group Mild TBI Task Force. Expert panel survey to update the American Congress of Rehabilitation Medicine definition of mild traumatic brain injury. *Arch Phys Med Rehabil*. 2021;102(1):76-86. doi:10.1016/j.apmr.2020.08.022

40. Leddy JJ, Haider MN, Ellis MJ, et al. Early subthreshold aerobic exercise for sport-related concussion: a randomized clinical trial. *JAMA Pediatr*. 2019;173(4):319-325. doi:10.1001/jamapediatrics.2018.4397

41. Lal A, Kolakowsky-Hayner SA, Ghajar J, Balamane M. The effect of physical exercise after a concussion: a systematic review and meta-analysis. *Am J Sports Med*. 2018;46(3):743-752. doi:10.1177/0363546517706137

SUPPLEMENT 1.
eFigure 1. CONSORT Diagram
eTable 1. Completion Rates for Outcomes
eTable 2. Numbers of Impaired Outcomes
eTable 3. Correction for Multiple Comparisons for All TBI Patients, mTBI Patients, and Patients With mTBI and Negative CT Scan on Admission
eResults. Supplementary Analysis
eFigure 2. SR-TBI Outcomes Odds Ratio at 3- and 6-Months Post-Injury for Patients With Assessments Both at 3- and 6-Months Post-Injury

SUPPLEMENT 2.
Nonauthor Collaborators

SUPPLEMENT 3.
Data Sharing Statement

Supplementary Online Content

eFigure 1. CONSORT flow diagram.

Enrollment

CENTER-TBI core database (n= 4509)

Excluded based on Place of Injury:
Street / Highway (n= 2257)
Home / Domestic (n = 1158)
Work / School / Military = (n = 299)
Public location (n = 359)
Other / Unknown / missing (n = 124)

Place of Injury:
Sport / Recreational (n = 312)

Excluded based on Injury cause:
Road traffic accident: (n = 25)
Violence / Attack (n = 2)

SR-TBI (n = 285)

Non-Sport TBI: (n = 4224)

Excluded based on age <16: (n = 29)

Excluded based on age <16: (n = 120)

Adults with SR-TBI: (n = 256)

Adults with Non-Sport TBI: (n = 4104)

eTable 1a. Completion rates for outcomes at each timepoint, % out of 4360 patients

Outcome	N at 3 months (%)	N at 6 months (%)
GOSE	3650 (84)	3674 (84)
SF-12v2 PCS	2222 (51)	2224 (51)
SF-12v2 MCS	2222 (51)	2224 (51)
RPQ	2084 (48)	2167 (50)
PHQ-9	2044 (47)	2125 (49)
GAD-7	2039 (47)	2122 (49)
PCL-5	2037 (47)	2116 (49)

Note. N = sample size.

eTable 1b Completion rates for outcomes at each timepoint, % out of 256 SR-TBI patients

Outcome (SR-TBI)	N at 3 months (%)	N at 6 months (%)
GOSE	222 (87)	223 (87)
SF-12v2 PCS	165 (64)	160 (63)
SF-12v2 MCS	165 (64)	160 (63)
RPQ	158 (62)	156 (61)
PHQ-9	152 (59)	155 (60)
GAD-7	151 (59)	153 (60)
PCL-5	157 (61)	155 (60)

Note. N = sample size.

eTable 1c Completion rates for outcomes at each timepoint, % out of 4104 non-SR-TBI patients

Outcome (TBI)	N at 3 months (%)	N at 6 months (%)
GOSE	3428 (84)	3451 (84)
SF-12v2 PCS	2057 (50)	2064 (50)
SF-12v2 MCS	2057 (50)	2064 (50)
RPQ	1926 (47)	2011 (49)
PHQ-9	1892 (46)	1970 (48)
GAD-7	1888 (46)	1969 (48)
PCL-5	1880 (46)	1961 (48)

Note. N = sample size.

eTable 2. Numbers (percentages and 95% confidence intervals) of impaired outcomes at 3 and 6 months.

Timepoint	Outcome measure	SR-TBI	mild SR-TBI	mild SR-TBI & negative CT	Non-sport TBI	Non-sport mild TBI	Non-sport mild TBI & negative CT
		n (% [95% CI])	n (% [95% CI])	n (% [95% CI])	n (% [95% CI])	n (% [95% CI])	n (% [95% CI])
3 months	GOSE	115 (52 [45-56])	70 (42 [35-49])	32 (33 [24-43])	2390 (70 [68-72])	1289 (59 [57-61])	524 (48 [45-51])
	RPQ	35 (22 [16-29])	23 (19 [13-27])	14 (22 [12-34])	587 (31 [29-33])	409 (28 [26-31])	167 (23 [20-27])
	PHQ-9	20 (13 [8-20])	14 (12 [7-20])	8 (13 [6-24])	379 (20 [18-22])	270 (19 [17-21])	126 (18 [15-21])
	GAD-7	11 (7 [4-12])	6 (5 [2-11])	4 (7 [2-16])	325 (17 [16-19])	238 (17 [15-19])	108 (15 [12-18])
	PCL-5	5 (3 [1-7])	2 (2 [0-6])	0	213 (11 [10-13])	165 (12 [10-13])	83 (12 [10-14])
	PCS	36 (22 [16-29])	22 (18 [11-26])	10 (14 [7 – 28])	787 (38 [36-40])	511 (36 [34-39])	247 (36 [32-39])
	MCS	38 (23 [19-30])	27 (21 [14-29])	17 (24 [15-36])	580 (29 [27-31])	405 (29 [27-31])	181 (27 [23-30])
6 months	GOSE	103 (46 [40-53])	65 (39 [31-46])	30 (31 [22-41])	2233 (65 [63-67])	1146 (52 [50-54])	437 (40 [37-43])
	RPQ	22 (14 [9-21])	15 (12 [7-19])	5 (7 [2-16])	603 (30 [28-32])	411 (28 [26-30])	184 (25 [22-29])
	PHQ-9	11 (7 [4-12])	6 (5 [2-10])	3 (4 [1-12])	370 (19 [17-21])	257 (18 [16-20])	127 (18 [15-21])
	GAD-7	12 (8 [4-13])	6 (5 [2-11])	1 (1 [0-8])	328 (17 [15-18])	244 (17 [15-19])	110 (16 [13-19])
	PCL-5	4 (3 [1-6])	2 (2 [0-6])	0	196 (10 [9-11])	151 (10 [9-12])	74 (10 [8-13])
	PCS	27 (17 [11-23])	17 (13 [8-21])	7 (11 [5-21])	631 (31 [28-33])	410 (29 [27-32])	189 (29 [24-31])
	MCS	22 (14 [9-20])	11 (9 [5-16])	5 (7 [2-15])	524 (26 [24-28])	354 (26 [24-28])	166 (25 [22-28])

Abbreviations: GOSE = Glasgow Outcome Score Extended. RPQ = Rivermead Post-concussion Symptoms Questionnaire. PHQ-9 = Patient Health Questionnaire 9. GAD-7 = Generalised Anxiety Disorder 7. PCL-5 = Posttraumatic Stress Disorder Checklist 5. PCS = Physical Component Summary. MCS = Mental Component Summary.

eTable 3a. Correction for multiple comparisons with the use of FDR (false discovery rate) for the comparison of the outcomes of SR-TBI and non-sports TBI for all TBI patients. The table gives the original *P* values from binary logistic regression, the critical *P* values at a 5% FDR rate, and the FDR corrected *P* values.

Rank	Variable	Original *P* value	Critical Value	Adjusted *P* value	Significance
1	RPQ 6	0.001	0.004	0.01	Yes
2	PHQ-9 6	0.002	0.007	0.01	Yes
3	PCL-5 6	0.004	0.01	0.02	Yes
4	PCL-5 3	0.005	0.01	0.02	Yes
5	MCS 6	0.007	0.02	0.02	Yes
6	PCS 3	0.007	0.02	0.02	Yes
7	GAD-7 6	0.01	0.03	0.03	Yes
8	GAD-7 3	0.03	0.03	0.05	Yes
9	GOSE 3	0.05	0.03	0.07	No
10	PCS 6	0.15	0.04	0.21	No
11	GOSE 6	0.17	0.04	0.22	No
12	RPQ 3	0.21	0.04	0.24	No
13	MCS 3	0.32	0.05	0.34	No
14	PHQ-9 3	0.44	0.05	0.44	No

eTable 3b. Correction for multiple comparisons with the use of FDR (false discovery rate) for the comparison of the outcomes of SR-TBI and non-sports TBI for patients with mTBI. The table gives the original *P* values from binary logistic regression, the critical *P* values at a 5% FDR rate, and the FDR corrected *P* values.

Rank	Variable	Original *P* value	Critical Value	Adjusted *P* value	Significance
1	MCS 6	<.001	0.004	0.008	Yes
2	PHQ-9 6	0.002	0.007	0.01	Yes
3	RPQ 6	0.003	0.01	0.01	Yes
4	PCL-5 6	0.005	0.01	0.02	Yes
5	GAD-7 6	0.007	0.02	0.02	Yes
6	PCL-5 3	0.007	0.02	0.02	Yes
7	PCS 3	0.008	0.03	0.02	Yes
8	GAD-7 3	0.02	0.03	0.04	Yes
9	GOSE 3	0.02	0.03	0.04	Yes
10	PCS 6	0.03	0.04	0.04	Yes
11	RPQ 3	0.12	0.04	0.15	No
12	MCS 3	0.13	0.04	0.15	No
13	GOSE 6	0.32	0.05	0.34	No
14	PHQ-9 3	0.4	0.05	0.4	No

Note. GOSE = Glasgow Outcome Score Extended. RPQ = Rivermead Post-concussion Symptoms Questionnaire. PHQ-9 = Patient Health Questionnaire. GAD-7 = Generalised Anxiety Disorder. PCL-5 = Posttraumatic Stress Disorder Checklist. PCS = Physical Component Summary. MCS = Mental Component Summary.

eTable 3c. Correction for multiple comparisons with the use of FDR (false discovery rate) for the comparison of outcomes of SR-TBI and non-sports TBI for patients with mTBI and negative CT scan on admission. The table gives the original *P* values from binary logistic regression, the critical *P* values at a 5% FDR rate, and the FDR corrected *P* values.

Rank	Variable	Original *P* value	Critical Value	Adjusted *P* value	Significance
1	MCS 6	0.002	0.005	0.02	Yes
2	RPQ 6	0.006	0.009	0.03	Yes
3	PHQ-9 6	0.006	0.01	0.02	Yes
4	GOSE 3	0.03	0.02	0.07	No
5	PCS 6	0.1	0.02	0.22	No
6	PCS 3	0.1	0.03	0.19	No
7	GAD-7 3	0.17	0.03	0.27	No
8	GOSE 6	0.48	0.04	0.65	No
9	PHQ-9 3	0.53	0.04	0.65	No
10	MCS 3	0.7	0.05	0.77	No
11	RPQ 3	0.88	0.05	0.88	No

Note. GOSE = Glasgow Outcome Score Extended. RPQ = Rivermead Post-concussion Symptoms Questionnaire. PHQ-9 = Patient Health Questionnaire. GAD-7 = Generalised Anxiety Disorder. PCL-5 = Posttraumatic Stress Disorder Checklist. PCS = Physical Component Summary. MCS = Mental Component Summary.

eResults. Supplementary Analysis

To investigate outcome trends from 3 to 6 months an analysis was conducted of data from patients assessed at both timepoints. The number of patients with outcome information both at 3 and 6 months can be found on Table 2 of the supplementary material. Binary logistic regressions, similar to the ones performed in whole database, were done on those samples.

SR-TBI patients were found to be 1.4[1.003-1.96] times more likely to have returned to normal life at 3 months (P = .05) compared to patient with TBI from other causes, this difference was absent at 6 months post-injury (P = .18; Figure 2). SR-TBI patients were also found to be 2.27 [1.35-3.83] times more likely to have better physical health related quality of life 3 months post-injury (P = .002), but this difference was again absent at 6 months (P = .23). Contrary to that, SR-TBI patients not more likely to have better MCS score 3 months (P = .172) post injury but were 2.23 [1.19-4.16] times more likely to have a better MCS score at 6 months (p = .01).

SR-TBI patients concussion symptom outcomes did not differ from the rest of the sample at the 3 months timepoint (P = .15), however at 6 months SR-TBI patients were 2.46[1.39-4.38] times less likely to have persistent post-concussion symptoms (P=.002).

Concerning mental health outcomes, SR-TBI patients did not differ in depression symptoms at 3 months post injury (P = .45) but were 3.89[1.54-9.83] times less likely to have depressive symptoms compared to the rest of the sample (P = .005). SR-TBI patients were found to be 2.65 [1.19-5.89] and 3.29 [1.30-8.36] times less likely to have anxiety symptoms at 3 and 6 months post-injury respectively. Similarly, SR-TBI patients were found to be 3.49[1.25-9.76] and 6.35[1.53-26.31] times less likely to have PTSD symptoms at 3 and 6 months post-injury respectively.

All P values remained below the chosen level of significance (.05) after correction for multiple comparison, apart from the GOSE score at 3 months.

The number of patients with mTBI and mTBI with negative CT scan with outcome measures both at 3 and 6 months was too small, so analyses on those subsamples were not performed.

eFigure 2. SR-TBI outcomes odds ratio at 3- and 6-months post-injury (Only for patients with assessments both at 3- and 6-months post-injury).

	OR (95% CI)	P
GOSE 3	1.40 (1.00-1.96)	.07
PCS 6	1.39 (0.80-2.40)	.25
MCS 3	1.42 (0.88-2.24)	.21
RPQ 3	1.41 (0.88-2.27)	.21
PHQ-9 3	1.25 (0.70-2.25)	.45
GAD-7 3*	2.65 (1.19-5.88)	.03
PCL-5 3*	3.49 (1.25-9.76)	.03
GOSE 6	1.26 (0.90-1.77)	.21
PCS 6	1.39 (0.80-2.39)	.25
MCS 6*	2.23 (1.19-4.16)	.01
RPQ 6*	2.47 (1.39-4.38)	.01
PHQ-9 6*	3.89 (1.54-9.83)	.02
GAD-7 6*	3.29 (1.30-8.35)	.01
PCL-5 6*	6.35 (1.53-19.96)	.03

Odds ratio (0.1 — 1 — 10)
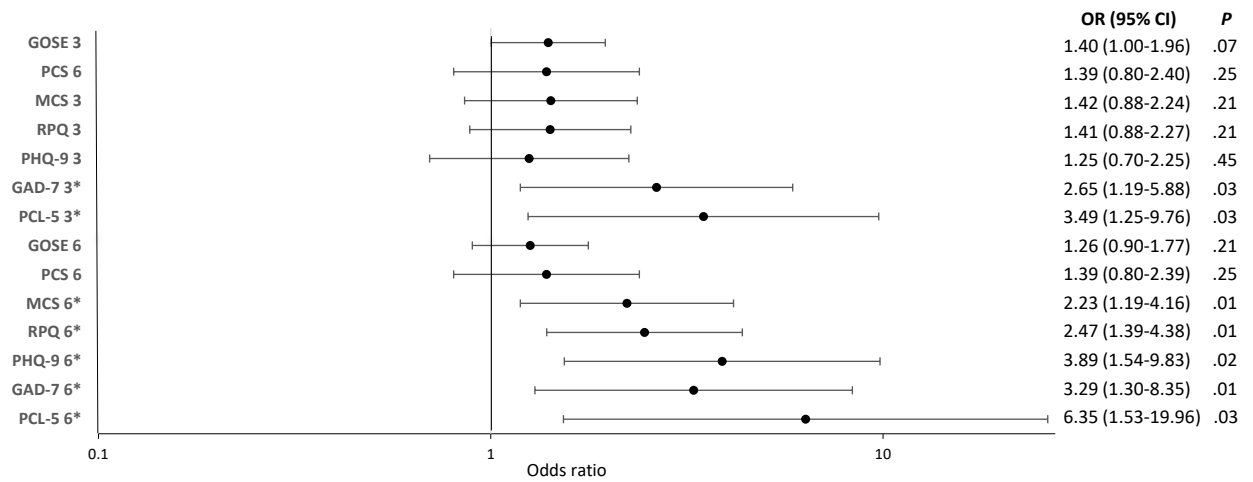
Note. *Denotes significant P value. GOSE = Glasgow Outcome Score Extended. RPQ = Rivermead Post-concussion Symptoms Questionnaire. PHQ-9 = Patient Health Questionnaire. GAD-7 = Generalised Anxiety Disorder. PCL-5 = Posttraumatic Stress Disorder Checklist. PCS = Physical Component Summary. MCS = Mental Component Summary. Horizontal lines represent 95% confidence intervals. Vertical like represents an odds ratio of 1.

Supplemental Online Content: Nonauthor Collaborators

*Indicates required information. Only first name, last name, and suffix will appear in PubMed.

*Group Name(s): The CENTER-TBI participants and investigators							
*First Name and Middle Initial(s)	*Last Name	*Suffix (eg, Jr, III)	Academic Degrees	Institution	Location (city, state/province, country)	Role or Contribution, eg, chair, principal investigator	Group (if more than 1 Group listed in the byline) and/or Subgroup (eg, Steering Committee)
Cecilia	Ackerlund			Karolinska Institutet, INCF Internatio	Stockholm, Sweden	CENTER-TBI Participant + Investigator	
Krisztina	Amrein			János Szentágothai Research Centre,	Pécs, Hungary	CENTER-TBI Participant + Investigator	
Nada	Andelic			Division of Surgery and Clinical Neuro	Oslo, Norway	CENTER-TBI Participant + Investigator	
Lasse	Andreassen			Department of Neurosurgery, Univers	Tromso, Norway	CENTER-TBI Participant + Investigator	
Audny	Anke			Department of Physical Medicine and	Tromso, Norway	CENTER-TBI Participant + Investigator	
Anna	Antoni			Trauma Surgery, Medical University V	Vienna, Austria	CENTER-TBI Investigator	
Gérard	Audibert			Department of Anesthesiology & Inte	Nancy, France	CENTER-TBI Investigator	
Philippe	Azouvi			Raymond Poincare hospital, Assistanc	Paris, France	CENTER-TBI Participant	
Maria Luisa	Azzolini			Department of Anesthesiology & Inte	Milan, Italy	CENTER-TBI Investigator	
Ronald	Bartels			Department of Neurosurgery, Radbou	Nijmegen, Netherlands	CENTER-TBI Investigator	
Pál	Barzó			Department of Neurosurgery, Univers	Szeged, Hungary	CENTER-TBI Investigator	
Romuald	Beauvais			International Projects Management,	Munchen, Germany	CENTER-TBI Participant	
Ronny	Beer			Department of Neurology, Neurologi	Innsbruck, Austria	CENTER-TBI Investigator	
Bo-Michael	Bellander			Deparment of Neurosurgery & Anest	Stockholm, Sweden	CENTER-TBI Investigator	
Antonio	Belli			NIHR Surgical Reconstruction and Mi	Birmingham, UK	CENTER-TBI Investigator	
Habib	Benali			Anesthesie-Réanimation, Assistance	Paris, France	CENTER-TBI Participant + Investigator	
Maurizio	Berardino			Department of Anesthesia & ICU, AO	Torino, Italy	CENTER-TBI Investigator	
Luigi	Beretta			Department of Anesthesiology & Inte	Milan, Italy	CENTER-TBI Investigator	
Morten	Blaabjerg			Department of Neurology, Odense U	Odense, Denmark	CENTER-TBI Participant + Investigator	
Peter	Bragge			BehaviourWorks Australia, Monash S	Melbourne, Australia	CENTER-TBI Participant	
Alexandra	Brazinova			Department of Public Health, Faculty	Trnava, Slovakia	CENTER-TBI Participant	
Vibeke	Brinck			Quesgen Systems Inc., Burlingame, C	Burlingame, California, USA	CENTER-TBI Participant	
Joanne	Brooker			Australian & New Zealand Intensive	Melbourne, Australia	CENTER-TBI Participant	
Camilla	Brorsson			Department of Surgery and Periopera	Umea, Sweden	CENTER-TBI Investigator	
Andras	Buki			Department of Neurosurgery, Medica	Pecs, Hungary	CENTER-TBI Participant + Investigator	
Monika	Bullinger			Department of Medical Psychology, U	Hamburg, Germany	CENTER-TBI Associated Participant	
Manuel	Cabeleira			Brain Physics Lab, Division of Neurosu	Cambridge, UK	CENTER-TBI Participant + Investigator	
Alessio	Caccioppola			Neuro ICU, Fondazione IRCCS Cà G	Milan, Italy	CENTER-TBI Participant + Investigator	
Emiliana	Calappi			Neuro ICU, Fondazione IRCCS Cà G	Milan, Italy	CENTER-TBI Participant + Investigator	

*Indicates required information. Only first name, last name, and suffix will appear in PubMed.

*First Name and Middle Initial(s)	*Last Name	*Suffix (eg, Jr, III)	Academic Degrees	Institution	Location (city, state/province, country)	Role or Contribution, eg, chair, principal investigator	Group (if more than 1 Group listed in the byline) and/or Subgroup (eg, Steering Committee)
Maria Rosa	Calvi			Department of Anesthesiology & Inte	Milan, Italy	CENTER-TBI Investigator	
Peter	Cameron			ANZIC Research Centre, Monash Univ	Melbourne, Australia	CENTER-TBI Participant	
Guillermo	Carbayo Lozano			Department of Neurosurgery, Hospit	Bilbao, Spain	CENTER-TBI Investigator	
Marco	Carbonara			Neuro ICU, Fondazione IRCCS Cà G	Milan, Italy	CENTER-TBI Participant + Investigator	
Ana M.	Castaño-León			Department of Computing, Imperial (	London, UK	CENTER-TBI Participant	
Simona	Cavallo			Department of Anesthesia & ICU, AO	Torino, Italy	CENTER-TBI Investigator	
Giorgio	Chevallard			NeuroIntensive Care, Niguarda Ho	Niguarda, Italy	CENTER-TBI Investigator	
Arturo	Chieregato			NeuroIntensive Care, Niguarda Ho	Niguarda, Italy	CENTER-TBI Investigator	
Giuseppe	Citerio			School of Medicine and Surgery, Univ	Milano, Italy	CENTER-TBI Participant + Investigator + MC	
Hans	Clusmann			Department of Neurosurgery, Medica	Aachen, Germany	CENTER-TBI Investigator	
Mark Steven	Coburn			Department of Anesthesiology and	Bonn, Germany	CENTER-TBI Investigator	
Jonathan	Coles			Department of Anesthesia & Neuroin	Cambridge, UK	CENTER-TBI Participant + Investigator	
Jamie D.	Cooper			School of Public Health & PM, Monas	Melbourne, Australia	CENTER-TBI Participant + Investigator	
Marta	Correia			Radiology/MRI department, MRC Cog	Cambridge, UK	CENTER-TBI Associated Participant	
Amra	Čović			Institute of Medical Psychology and N	Göttingen, Germany	CENTER-TBI Participant	
Nicola	Curry			Oxford University Hospitals NHS Trus	Oxford, UK	CENTER-TBI Participant	
Endre	Czeiter			Department of Neurosurgery, Medica	Pecs, Hungary	CENTER-TBI Participant + Investigator	
Marek	Czosnyka			Brain Physics Lab, Division of Neurosu	Cambridge, UK	CENTER-TBI Participant + Investigator	
Claire	Dahyot-Fizelier			Intensive care Unit, CHU Poitiers, Poi	Poitiers, France	CENTER-TBI Investigator	
Paul	Dark			University of Manchester NIHR Biome	Salford, UK	CENTER-TBI Investigator	
Helen	Dawes			Movement Science Group, Faculty of	Oxford, UK	CENTER-TBI Participant	
Véronique	De Keyser			Department of Neurosurgery, Antwe	Edegem, Belgium	CENTER-TBI Participant + Investigator	
Vincent	Degos			Anesthesie-Réanimation, Assistance I	Paris, France	CENTER-TBI Participant + Investigator	
Francesco	Della Corte			Department of Anesthesia & Intensiv	Novara, Italy	CENTER-TBI Investigator	
Hugo	den Boogert			Department of Neurosurgery, Radbou	Nijmegen, Netherlands	CENTER-TBI Investigator	
Bart	Depreitere			Department of Neurosurgery, Univer	Leuven, Belgium	CENTER-TBI Investigator	
Đula	Đilvesi			Department of Neurosurgery, Clinical	Novi Sad, Serbia	CENTER-TBI Investigator	
Abhishek	Dixit			Division of Anaesthesia, University of	Cambridge, UK	CENTER-TBI Participant + Investigator	
Emma	Donoghue			ANZIC Research Centre, Monash Univ	Melbourne, Australia	CENTER-TBI Participant	
Jens	Dreier			Interdisciplinary Neuro Intensive Car	Berlin, Germany	CENTER-TBI Participant + Investigator	
Guy-Loup	Dulière			Intensive Care Unit, CHR Citadelle , Li	Liège, Belgium	CENTER-TBI Investigator	

*Indicates required information. Only first name, last name, and suffix will appear in PubMed.

*First Name and Middle Initial(s)	*Last Name	*Suffix (eg, Jr, III)	Academic Degrees	Institution	Location (city, state/province, country)	Role or Contribution, eg, chair, principal investigator	Group (if more than 1 Group listed in the byline) and/or Subgroup (eg, Steering Committee)
Ari	Ercole			Division of Anaesthesia, University of	Cambridge, UK	CENTER-TBI Participant + Investigator	
Patrick	Esser			Movement Science Group, Faculty of	Oxford, UK	CENTER-TBI Participant	
Erzsébet	Ezer			Department of Anaesthesiology and	Pécs, Hungary	CENTER-TBI Participant + Investigator	
Martin	Fabricius			Departments of Neurology, Clinical N	Copenhagen, Denmark	CENTER-TBI Participant + Investigator	
Valery L.	Feigin			National Institute for Stroke and App	Auckland, New Zealand	CENTER-TBI Participant	
Kelly	Foks			Department of Neurology, Erasmus M	Rotterdam, Netherlands	CENTER-TBI Participant + Investigator	
Shirin	Frisvold			Department of Anesthesiology and In	Tromso, Norway	CENTER-TBI Investigator	
Alex	Furmanov			Department of Neurosurgery, Hadass	Jerusalem, Israel	CENTER-TBI Investigator	
Pablo	Gagliardo			Fundación Instituto Valenciano de Ne	Valencia, Spain	CENTER-TBI Associated Participant	
Damien	Galanaud			Anesthesie-Réanimation, Assistance	Paris, France	CENTER-TBI Participant + Investigator	
Dashiell	Gantner			ANZIC Research Centre, Monash Univ	Melbourne, Australia	Oz ENTER	
Guoyi	Gao			Department of Neurosurgery, Shangh	Shanghai, China	CENTER-TBI Participant	
Pradeep	George			Karolinska Institutet, INCF Internatior	Stockholm, Sweden	CENTER-TBI Participant	
Alexandre	Ghuysen			Emergency Department, CHU , Liège,	Liège, Belgium	CENTER-TBI Investigator	
Lelde	Giga			Neurosurgery clinic, Pauls Stradins Cl	Riga, Latvia	CENTER-TBI Investigator	
Ben	Glocker			Department of Computing, Imperial (	London, UK	CENTER-TBI Participant	
Jagoš	Golubović			Department of Neurosurgery, Clinica	Novi Sad, Serbia	CENTER-TBI Investigator	
Pedro A.	Gomez			Department of Neurosurgery, Hospita	Madrid, Spain	CENTER-TBI Investigator	
Johannes	Gratz			Department of Anesthesia, Critical Ca	Vienna, Austria	CENTER-TBI Participant	
Benjamin	Gravesteijn			Department of Public Health, Erasmu	Rotterdam, Netherlands	CENTER-TBI Participant	
Francesca	Grossi			Department of Anesthesia & Intensiv	Novara, Italy	CENTER-TBI Investigator	
Russell L.	Gruen			College of Health and Medicine, Aust	Canberra, Australia	CENTER-TBI Associated Participant	
Deepak	Gupta			Department of Neurosurgery, Neuros	Delhi, India	CENTER-TBI Associated participant + Investigator	
Juanita A.	Haagsma			Department of Public Health, Erasmu	Rotterdam, Netherlands	CENTER-TBI Participant	
Iain	Haitsma			Department of Neurosurgery, Erasmu	Rotterdam, Netherlands	CENTER-TBI Investigator	
Raimund	Helbok			Department of Neurology, Neurologic	Innsbruck, Austria	CENTER-TBI Investigator	
Eirik	Helseth			Department of Neurosurgery, Oslo U	Oslo, Norway	CENTER-TBI Participant + Investigator	
Lindsay	Horton			Division of Psychology, University of !	Stirling, UK	CENTER-TBI Participant	
Jilske	Huijben			Department of Public Health, Erasmu	Rotterdam, Netherlands	CENTER-TBI Participant	
Peter J.	Hutchinson			Division of Neurosurgery, Departmen	Cambridge, UK	CENTER-TBI Participant + Investigator	
Bram	Jacobs			Department of Neurology, University	Groningen, Netherlands	CENTER-TBI Investigator	

Supplemental Online Content: Nonauthor Collaborators

*Indicates required information. Only first name, last name, and suffix will appear in PubMed.

*First Name and Middle Initial(s)	*Last Name	*Suffix (eg, Jr, III)	Academic Degrees	Institution	Location (city, state/province, country)	Role or Contribution, eg, chair, principal investigator	Group (if more than 1 Group listed in the byline) and/or Subgroup (eg, Steering Committee)
Stefan	Jankowski			Neurointensive Care , Sheffield Teach	Sheffield, UK	CENTER-TBI Investigator	
Mike	Jarrett			Quesgen Systems Inc., Burlingame, C	Burlingame, California, USA	CENTER-TBI Participant	
Ji-yao	Jiang			Department of Neurosurgery, Shangh	Shanghai, China	CENTER-TBI Participant	
Faye	Johnson			Salford Royal Hospital NHS Foundatic	Salford, UK	CENTER-TBI Investigator	
Kelly	Jones			National Institute for Stroke and App	Auckland, New Zealand	CENTER-TBI Participant	
Mladen	Karan			Department of Neurosurgery, Clinical	Novi Sad, Serbia	CENTER-TBI Investigator	
Angelos G.	Kolias			Division of Neurosurgery, Departmen	Cambridge, UK	CENTER-TBI Participant + Investigator	
Erwin	Kompanje			Department of Intensive Care and De	Rotterdam, Netherlands	CENTER-TBI Participant	
Daniel	Kondziella			Departments of Neurology, Clinical N	Copenhagen, Denmark	CENTER-TBI Investigator	
Evgenios	Kornaropoulos			Division of Anaesthesia, University	Cambridge, UK	CENTER-TBI Investigator	
Lars-Owe	Koskinen			Department of Neurosurgery, Umea	Umea, Sweden	CENTER-TBI Investigator	
Noémi	Kovács			Hungarian Brain Research Program -	Pécs, Hungary	CENTER-TBI Participant + Investigator	
Ana	Kowark			Department of Anesthesiology, Unive	Aachen, Germany	CENTER-TBI Investigator	
Alfonso	Lagares			Department of Neurosurgery, Hospit	Madrid, Spain	CENTER-TBI Investigator	
Linda	Lanyon			Karolinska Institutet, INCF Internatior	Stockholm, Sweden	CENTER-TBI Participant + MC	
Steven	Laureys			Cyclotron Research Center , Universit	Liège, Belgium	CENTER-TBI Participant + Investigator	
Fiona	Lecky			Centre for Urgent and Emergency	Sheffield, UK	CENTER-TBI Participant + Investigator + MC	
Didier	Ledoux			Cyclotron Research Center , Universit	Liège, Belgium	CENTER-TBI Participant + Investigator	
Rolf	Lefering			Institute of Research in Operative Me	Cologne, Germany	CENTER-TBI Participant	
Valerie	Legrand			VP Global Project Management CNS,	Paris, France	CENTER-TBI Participant	
Aurelie	Lejeune			Department of Anesthesiology-Intens	Lille, France	CENTER-TBI Investigator	
Leon	Levi			Department of Neurosurgery, Ramba	Haifa, Israel	CENTER-TBI Investigator	
Roger	Lightfoot			Department of Anesthesiology & Inte	Southhampton, UK	CENTER-TBI Investigator	
Hester	Lingsma			Department of Public Health, Erasmu	Rotterdam, Netherlands	CENTER-TBI Participant + MC	
Marc	Maegele			Cologne-Merheim Medical Center (CI	Cologne, Germany	CENTER-TBI Participant	
Marek	Majdan			Department of Public Health, Faculty	Trnava, Slovakia	CENTER-TBI Participant	
Alex	Manara			Intensive Care Unit, Southmead Hosp	Bristol, UK	CENTER-TBI Investigator	
Geoffrey	Manley			Department of Neurological Surgery,	San Francisco, California, U	CENTER-TBI Participant	
Hugues	Maréchal			Intensive Care Unit, CHR Citadelle , Li	Liège, Belgium	CENTER-TBI Investigator	
Costanza	Martino			Department of Anesthesia & Intensiv	Cesena, Italy	CENTER-TBI Investigator	
Julia	Mattern			Department of Neurosurgery, Univer	Heidelberg, Germany	CENTER-TBI Participant	

*Indicates required information. Only first name, last name, and suffix will appear in PubMed.

*First Name and Middle Initial(s)	*Last Name	*Suffix (eg, Jr, III)	Academic Degrees	Institution	Location (city, state/province, country)	Role or Contribution, eg, chair, principal investigator	Group (if more than 1 Group listed in the byline) and/or Subgroup (eg, Steering Committee)
Catherine	McMahon			Department of Neurosurgery, The Wa	Liverpool, UK	CENTER-TBI Investigator	
Béla	Melegh			Department of Medical Genetics, Uni	Pécs, Hungary	CENTER-TBI Participant	
Tomas	Menovsky			Department of Neurosurgery, Antwe	Edegem, Belgium	CENTER-TBI Participant + Investigator	
Ana	Mikolic			Department of Public Health, Erasmu	Rotterdam, Netherlands	CENTER-TBI Participant	
Benoit	Misset			Cyclotron Research Center , Universit	Liège, Belgium	CENTER-TBI Participant + Investigator	
Visakh	Muraleedharan			Karolinska Institutet, INCF Internatior	Stockholm, Sweden	CENTER-TBI Participant + DCTF	
Lynnette	Murray			ANZIC Research Centre, Monash Univ	Melbourne, Australia	Oz ENTER	
Nandesh	Nair			Department of Neurosurgery, Antwe	Antwerp, Belgium	CENTER-TBI Participant	
Ancuta	Negru			Department of Neurosurgery, Emerge	Timisoara, Romania	CENTER-TBI Investigator	
David	Nelson			Karolinska Institutet, INCF Internatior	Stockholm, Sweden	CENTER-TBI Participant + Investigator	
Virginia	Newcombe			Division of Anaesthesia, University of	Cambridge, UK	CENTER-TBI Participant + Investigator	
Daan	Nieboer			Department of Public Health, Erasmu	Rotterdam, Netherlands	CENTER-TBI Participant	
József	Nyirádi			János Szentágothai Research Centre,	Pécs, Hungary	CENTER-TBI Participant + Investigator	
Matej	Oresic			School of Medical Sciences, Örebro U	Örebro, Sweden	CENTER-TBI Participant	
Fabrizio	Ortolano			Neuro ICU, Fondazione IRCCS Cà G	Milan, Italy	CENTER-TBI Participant + Investigator	
Olubukola	Otesile			Centre for Urgent and Emergency	Sheffield, UK	CENTER-TBI Participant + Investigator	
Aarno	Palotie			Institute for Molecular Medicine Finla	Helsinki, Finland	CENTER-TBI Participant	
Paul M.	Parizel			Department of Radiology, University	Edegem, Belgium	CENTER-TBI Participant + Investigator	
Jean-François	Payen			Department of Anesthesiology & Inte	Grenoble, France	CENTER-TBI Investigator	
Natascha	Perera			International Projects Management,	Munchen, Germany	CENTER-TBI Participant	
Vincent	Perlbarg			Anesthesie-Réanimation, Assistance	Paris, France	CENTER-TBI Participant + Investigator	
Paolo	Persona			Department of Anesthesia & Intensiv	Padova, Italy	CENTER-TBI Investigator	
Wilco	Peul			Dept. of Neurosurgery, Leiden Univer	Leiden, Netherlands	CENTER-TBI Participant + Investigator + MC	
Anna	Piippo-Karjalainen			Department of Neurosurgery, Helsink	Helsinki, Finland	CENTER-TBI Investigator	
Matti	Pirinen			Institute for Molecular Medicine Finla	Helsinki, Finland	CENTER-TBI Participant	
Dana	Pisica			Department of Public Health, Erasmu	Rotterdam, Netherlands	CENTER-TBI Participant	
Horia	Ples			Department of Neurosurgery, Emerge	Timisoara, Romania	CENTER-TBI Investigator	
Suzanne	Polinder			Department of Public Health, Erasmu	Rotterdam, Netherlands	CENTER-TBI Participant	
Inigo	Pomposo			Department of Neurosurgery, Hospita	Bilbao, Spain	CENTER-TBI Investigator	
Jussi P.	Posti			Division of Clinical Neurosciences, De	Turku, Finland	CENTER-TBI Participant + Investigator	
Louis	Puybasset			Department of Anesthesiology and C	Paris, France	CENTER-TBI Participant + Investigator	

*Indicates required information. Only first name, last name, and suffix will appear in PubMed.

*First Name and Middle Initial(s)	*Last Name	*Suffix (eg, Jr, III)	Academic Degrees	Institution	Location (city, state/province, country)	Role or Contribution, eg, chair, principal investigator	Group (if more than 1 Group listed in the byline) and/or Subgroup (eg, Steering Committee)
Andreea	Rădoi			Neurotraumatology and Neurosurger	Barcelona, Spain	CENTER-TBI Investigator	
Arminas	Ragauskas			Department of Neurosurgery, Kaunas	Vilnius, Lithuania	CENTER-TBI Investigator	
Rahul	Raj			Department of Neurosurgery, Helsink	Helsinki, Finland	CENTER-TBI Investigator	
Malinka	Rambadagalla			Rezekne Hospital, Latvia	Rezekne, Latvia	CENTER-TBI Investigator	
Isabel	Retel Helmrich			Department of Public Health, Erasmu	Rotterdam, Netherlands	CENTER-TBI Participant	
Jonathan	Rhodes			Department of Anaesthesia, Critical (	Edinburgh, UK	CENTER-TBI Investigator	
Sylvia	Richardson			Director, MRC Biostatistics Unit, Cam	Cambridge, UK	CENTER-TBI Participant	
Sophie	Richter			Division of Anaesthesia, University of	Cambridge, UK	CENTER-TBI Participant + Investigator	
Samuli	Ripatti			Institute for Molecular Medicine Finla	Helsinki, Finland	CENTER-TBI Participant	
Saulius	Rocka			Department of Neurosurgery, Kaunas	Vilnius, Lithuania	CENTER-TBI Investigator	
Cecilie	Roe			Department of Physical Medicine and	Oslo, Norway	CENTER-TBI Participant + Investigator	
Olav	Roise			Division of Orthopedics, Oslo Univers	Oslo, Norway	CENTER-TBI Participant + Investigator	
Jonathan	Rosand			Broad Institute, Cambridge MA Harva	Boston, Massachusetts, US	CENTER-TBI Associated Participant	
Jeffrey	Rosenfeld			National Trauma Research Institute, 1	Melbourne, Australia	CENTER-TBI Participant	
Christina	Rosenlund			Department of Neurosurgery, Odens	Odense, Denmark	CENTER-TBI Investigator	
Guy	Rosenthal			Department of Neurosurgery, Hadass	Jerusalem, Israel	CENTER-TBI Investigator	
Rolf	Rossaint			Department of Anaesthesiology, Univ	Aachen, Germany	CENTER-TBI Associated participant + Investigator	
Sandra	Rossi			Department of Anesthesia & Intensiv	Padova, Italy	CENTER-TBI Investigator	
Daniel	Rueckert			Department of Computing, Imperial (	London, UK	CENTER-TBI Participant	
Martin	Rusnák			International Neurotrauma Research	Vienna, Austria	CENTER-TBI Participant	
Juan	Sahuquillo			Department of Neurosurgery, Vall d'H	Barcelona, Spain	CENTER-TBI Investigator	
Oliver	Sakowitz			Department of Neurosurgery, Univer	Heidelberg, Germany	CENTER-TBI Participant	
Renan	Sanchez-Porras			Klinik für Neurochirurgie, Klinikum Lu	Ludwigsburg, Germany	CENTER-TBI Participant + Investigator	
Janos	Sandor			Division of Biostatistics and Epidemic	Debrecen, Hungary	CENTER-TBI Participant	
Nadine	Schäfer			Cologne-Merheim Medical Center (CI	Cologne, Germany	CENTER-TBI Participant	
Silke	Schmidt			Department Health and Prevention, L	Greifswald, Germany	CENTER-TBI Participant	
Herbert	Schoechl			Department of Anaesthesiology and I	Salzburg, Austria	CENTER-TBI Associated Participant	
Guus	Schoonman			Department of Neurology, Elisabeth-	Tilburg, Netherlands	CENTER-TBI Investigator	
Rico Frederik	Schou			Department of Neuroanesthesia and	Odense, Denmark	CENTER-TBI Participant + Investigator	
Elisabeth	Schwendenwein			Trauma Surgery, Medical University V	Vienna, Austria	CENTER-TBI Investigator	
Ranjit D.	Singh			Dept. of Neurosurgery, Leiden Uni	Leiden, Netherlands	CENTER-TBI Investigator	

*Indicates required information. Only first name, last name, and suffix will appear in PubMed.

*First Name and Middle Initial(s)	*Last Name	*Suffix (eg, Jr, III)	Academic Degrees	Institution	Location (city, state/province, country)	Role or Contribution, eg, chair, principal investigator	Group (if more than 1 Group listed in the byline) and/or Subgroup (eg, Steering Committee)
Charlie	Sewalt			Department of Public Health, Erasmu	Rotterdam, Netherlands	CENTER-TBI Participant	
Toril	Skandsen			Department of Neuromedicine and N	Trondheim, Norway	CENTER-TBI Investigator	
Peter	Smielewski			Brain Physics Lab, Division of Neuros	Cambridge, UK	CENTER-TBI Participant + Investigator	
Abayomi	Sorinola			Department of Neurosurgery, Univer	Pécs, Hungary	CENTER-TBI Participant + Investigator	
Emmanuel	Stamatakis			Division of Anaesthesia, University of	Cambridge, UK	CENTER-TBI Participant	
Simon	Stanworth			Oxford University Hospitals NHS Trus	Oxford, UK	CENTER-TBI Participant	
Robert	Stevens			Division of Neuroscience Critical Care	Baltimore, Maryland, USA	CENTER-TBI Associated Participant	
Ewout W.	Steyerberg			Dept. of Department of Biomedical D	Leiden, Netherlands	CENTER-TBI Participant + MC	
Nino	Stocchetti			Department of Pathophysiology and	Milan, Italy	CENTER-TBI Participant + Investigator + MC	
Nina	Sundström			Department of Radiation Sciences, Bi	Umea, Sweden	CENTER-TBI Investigator	
Riikka	Takala			Perioperative Services, Intensive Care	Turku, Finland	CENTER-TBI Participant + Investigator	
Viktória	Tamás			Department of Neurosurgery, Univer	Pécs, Hungary	CENTER-TBI Participant + Investigator	
Tomas	Tamosuitis			Department of Neurosurgery, Kaunas	Vilnius, Lithuania	CENTER-TBI Investigator	
Mark Steven	Taylor			Department of Public Health, Faculty	Trnava, Slovak Republic	CENTER-TBI Participant	
Braden	Te Ao			National Institute for Stroke and App	Auckland, New Zealand	CENTER-TBI Participant	
Olli	Tenovuo			Division of Clinical Neurosciences, De	Turku, Finland	CENTER-TBI Participant + Investigator	
Alice	Theadom			National Institute for Stroke and App	Auckland, New Zealand	CENTER-TBI Participant	
Matt	Thomas			Intensive Care Unit, Southmead Hosp	Bristol, UK	CENTER-TBI Investigator	
Aurore	Thibaut			Cyclotron Research Center , Universit	Liège, Belgium	CENTER-TBI Participant	
Dick	Tibboel			Intensive Care and Department of Pe	Rotterdam, Netherlands	CENTER-TBI Participant	
Marjolijn	Timmers			Department of Intensive Care and De	Rotterdam, Netherlands	CENTER-TBI Participant	
Christos	Tolias			Department of Neurosurgery, Kings c	London, UK	CENTER-TBI Investigator	
Tony	Trapani			ANZIC Research Centre, Monash Univ	Melbourne, Australia	Oz ENTER	
Cristina Maria	Tudora			Department of Neurosurgery, Emerge	Timisoara, Romania	CENTER-TBI Investigator	
Andreas	Unterberg			Department of Neurosurgery, Univer	Heidelberg, Germany	CENTER-TBI Participant + Investigator	
Peter	Vajkoczy			Neurologie, Neurochirurgie und Psyc	Berlin, Germany	CENTER-TBI Investigator	
Egils	Valeinis			Neurosurgery clinic, Pauls Stradins Cl	Riga, Latvia	CENTER-TBI Investigator	
Shirley	Vallance			ANZIC Research Centre, Monash Univ	Melbourne, Australia	Oz ENTER	
Zoltán	Vámos			Department of Anaesthesiology and I	Pécs, Hungary	CENTER-TBI Participant + Investigator	
Mathieu	van der Jagt			Department of Intensive Care Adults,	Rotterdam, Netherlands	CENTER-TBI Investigator	
Joukje	van der Naalt			Department of Neurology, University	Groningen, Netherlands	CENTER-TBI Investigator	

*Indicates required information. Only first name, last name, and suffix will appear in PubMed.

*First Name and Middle Initial(s)	*Last Name	*Suffix (eg, Jr, III)	Academic Degrees	Institution	Location (city, state/province, country)	Role or Contribution, eg, chair, principal investigator	Group (if more than 1 Group listed in the byline) and/or Subgroup (eg, Steering Committee)
Gregory	Van der Steen			Department of Neurosurgery, Antwe	Edegem, Belgium	CENTER-TBI Participant	
Jeroen T.J.M.	van Dijck			Dept. of Neurosurgery, Leiden Univer	Leiden, Netherlands	CENTER-TBI Participant + Investigator	
Inge A.	van Erp			Dept. of Neurosurgery, Leiden Uni	Leiden, Netherlands	CENTER-TBI Investigator	
Thomas A.	van Essen			Dept. of Neurosurgery, Leiden Univer	Leiden, Netherlands	CENTER-TBI Participant + Investigator	
Wim	Van Hecke			icoMetrix NV, Leuven, Belgium	Leuven, Belgium	CENTER-TBI Participant	
Caroline	van Heugten			Movement Science Group, Faculty of	Oxford, UK	CENTER-TBI Participant	
Dominique	Van Praag			Psychology Department, Antwerp Un	Edegem, Belgium	CENTER-TBI Participant + Investigator	
Ernest	van Veen			Department of Public Health, Erasmu	Rotterdam, Netherlands	CENTER-TBI Participant	
Roel P.J.	van Wijk			Dept. of Neurosurgery, Leiden Univer	Leiden, Netherlands	CENTER-TBI Participant + Investigator	
Thijs	Vande Vyvere			icoMetrix NV, Leuven, Belgium	Edegem, Belgium	CENTER-TBI Participant + Investigator	
Alessia	Vargiolu			NeuroIntenisve Care Unit, Departmer	Monza, Italy	CENTER-TBI Participant + Investigator	
Emmanuel	Vega			Department of Anesthesiology-Intens	Lille, France	CENTER-TBI Investigator	
Kimberley	Velt			Department of Public Health, Erasmu	Rotterdam, Netherlands	CENTER-TBI Participant	
Jan	Verheyden			icoMetrix NV, Leuven, Belgium	Leuven, Belgium	CENTER-TBI Participant	
Paul M.	Vespa			Director of Neurocritical Care, Univer	Los Angeles, California, USA	CENTER-TBI Associated Participant	
Anne	Vik			Department of Neuromedicine and M	Trondheim, Norway	CENTER-TBI Investigator	
Rimantas	Vilcinis			Department of Neurosurgery, Kaunas	Kaunas, Lithuania	CENTER-TBI Investigator	
Victor	Volovici			Department of Neurosurgery, Erasmu	Rotterdam, Netherlands	CENTER-TBI Participant + Investigator	
Nicole	von Steinbüchel			Institute of Medical Psychology and N	Göttingen, Germany	CENTER-TBI Participant	
Daphne	Voormolen			Department of Public Health, Erasmu	Rotterdam, Netherlands	CENTER-TBI Participant	
Peter	Vulekovic			Department of Neurosurgery, Clinical	Novi Sad, Serbia	CENTER-TBI Investigator	
Kevin K.W.	Wang			Department of Emergency Medicine,	Gainesville, Florida, USA	CENTER-TBI Participant	
Daniel	Whitehouse			Division of Anaesthesia, University	Cambridge, UK	CENTER-TBI Investigator	
Eveline	Wiegers			Department of Public Health, Erasmu	Rotterdam, Netherlands	CENTER-TBI Participant	
Guy	Williams			Division of Anaesthesia, University of	Cambridge, UK	CENTER-TBI Participant	
Stefan	Winzeck			Division of Anaesthesia, University	Cambridge, UK	CENTER-TBI Investigator	
Stefan	Wolf			Interdisciplinary Neuro Intensive Care	Berlin, Germany	CENTER-TBI Participant + Investigator	
Zhihui	Yang			Department of Emergency Medicine,	Gainesville, Florida, USA	CENTER-TBI Participant	
Peter	Ylén			VTT Technical Research Centre, Tamp	Tampere, Finland	CENTER-TBI Participant	
Alexander	Younsi			Department of Neurosurgery, Univer	Heidelberg, Germany	CENTER-TBI Investigator	
Frederick A.	Zeiler			Division of Anaesthesia, University of	Cambridge, UK	CENTER-TBI Participant	

Supplemental Online Content: Nonauthor Collaborators

*Indicates required information. Only first name, last name, and suffix will appear in PubMed.

*First Name and Middle Initial(s)	*Last Name	*Suffix (eg, Jr, III)	Academic Degrees	Institution	Location (city, state/province, country)	Role or Contribution, eg, chair, principal investigator	Group (if more than 1 Group listed in the byline) and/or Subgroup (eg, Steering Committee)
Veronika	Zelinkova			Department of Public Health, Facu	Trnava, Slovakia	CENTER-TBI Investigator	
Agate	Ziverte			Neurosurgery clinic, Pauls Stradins Cl	Riga, Latvia	CENTER-TBI Investigator	
Tommaso	Zoerle			Neuro ICU, Fondazione IRCCS Cà G	Milan, Italy	CENTER-TBI Participant + Investigator	

Data Sharing Statement

Ntikas. Contrasting Characteristics and Outcomes of Sports- and Non–Sports-Related Traumatic Brain Injury. *JAMA Netw Open*. Published January 31, 2024. doi:10.1001/jamanetworkopen.2023.53318

Data
Data available: Yes
Data types: Deidentified participant data
How to access data: Individual patient data is available by application to CENTER-TBI (https://www.center-tbi.eu/data).
When available: beginning date: 09-08-2023

Supporting Documents
Document types: None

Additional Information
Who can access the data: Data will be made available to researchers whose proposed use of the data has been approved by the CENTER-TBI Management Committee
Types of analyses: Data will be made available for the purpose of the proposed analysis.
Mechanisms of data availability: After approval of a proposal and with a data access agreement