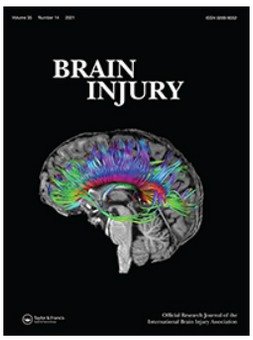

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BRAIN INJURY
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Health and cognition among adults with and without Traumatic Brain Injury: A matched case–control study

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ABSTRACT

Objectives: To evaluate associations between traumatic brain injury (TBI) and presence of health conditions, and to compare associations of health and cognition between TBI cases and controls.

Methods: This matched case–control study used data from the TBI Model Systems National Database (TBI cases) and Midlife in the United States II and Refresher studies (controls). 248 TBI cases were age-, sex-, race-, and education-matched without replacement to three controls. Cases and controls were compared on prevalence of 18 self-reported conditions, self-rated health, composite scores from the Brief Test of Adult Cognition by Telephone.

Results: The following conditions were significantly more prevalent among TBI cases versus controls: anxiety/depression (OR = 3.12, 95% CI: 2.20, 4.43, $p < .001$), chronic sleeping problems (OR = 2.76, 95% CI: 1.86, 4.10, $p < .001$), headache/migraine (OR = 2.61, 95% CI: 1.50, 4.54, $p = .0007$), and stroke (OR = 6.42, 95% CI: 2.93, 14.10, $p < .001$). The relationship between self-rated health and cognition significantly varied by TBI ($p_{interaction} = 0.002$).

Conclusion: Individuals with TBI have greater odds of selected neurobehavioral conditions compared to their demographically similar uninjured peers. Among persons with TBI there was a stronger association between poorer self-rated health and cognition than controls. TBI is increasingly conceptualized as a chronic disease; current findings suggest post-TBI health management requires cognitive supports.

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Brain injuries; traumatic; cognition; health; disease

Introduction

Traumatic brain injury (TBI) affects over 3.5 million individuals annually in the United States (1) and can result in longstanding physical, cognitive, and behavioral impairments (2,3). Once considered a discrete event with finite recovery, TBI is now widely considered a chronic condition that evolves over time, causing and/or accelerating the progression of secondary health conditions and often requiring lifelong management (4,5). Support for the conceptualization of TBI as a chronic health problem comes from a number of observational cohort studies assessing incidence and prevalence of particular health conditions following TBI, such as sleep disorders (6), post-traumatic epilepsy (7,8), hypopituitarism (9,10), and depression (11,12). Though lacking in direct comparisons, these TBI cohort studies have observed a high burden of certain medical and psychiatric diseases that seemingly exceed documented rates in the general population.

Some studies evaluating risk for dementia following TBI have directly compared unadjusted rates of various health conditions between individuals with and without TBI (13–18). These studies provide converging evidence that individuals with TBI have higher crude rates of disease compared to those without TBI. In these studies, individual health conditions are included in primary analyses insofar as they may potentially confound TBI-dementia associations. Limited data exists, however, concerning the prevalence of specific health conditions between comparable individuals with and without TBI. A matched comparison would limit potential confounding to understand if individuals with TBI have an elevated disease burden relative to their similar counterparts in the general population.

Multiple mechanisms may underlie elevated disease burden after TBI, including chronic systemic inflammation (19), neuroendocrine disturbance (9), and altered metabolism (20). TBI-related cognitive impairment likely has particularly important implications for overall post-TBI health. A range of health

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maintenance and promotion behaviors (e.g., scheduling/keeping medical appointments, planning healthy meals, taking medications as prescribed, minimizing substance use and other potentially deleterious health behaviors) are supported by neurological processes that are often selectively and chronically impaired following TBI.[3] Impaired cognition can also underlie and exacerbate other common consequences of TBI, such as mood disturbance and behavioral disinhibition. To our knowledge, the association between cognitive functioning and health after TBI compared to the general population has not been previously investigated.

Advancing our understanding of health burden and its associations with cognition among individuals with and without TBI requires direct comparison of harmonized data between TBI cases and uninjured controls. The primary objective of the present matched case–control study was to determine which health conditions were more prevalent in persons who are one-year post moderate-to-severe TBI compared to population-based matched controls. The secondary objective was to investigate whether associations between health and cognition varied by TBI. We hypothesized that cases with TBI would have greater health burden compared to matched controls, and the relationship between poor health and lower cognition would be stronger among TBI cases versus matched controls.

Methods

TBI participants

We enrolled and followed cases from nine inpatient rehabilitation centers that are part of the TBI Model Systems National Database (TBIMS NDB), a prospective, multicenter longitudinal cohort study funded by the National Institute on Disability, Independent Living, and Rehabilitation Research. We selected TBI cases enrolled in the TBIMS NDB from 2012 to 2017. TBIMS NDB inclusion criteria required eligible individuals to sustain a moderate-to-severe TBI, defined by one of the following: Glasgow Coma Scale score <13 on emergency department admission, loss of consciousness >30 min, post-traumatic amnesia >24 hours, or traumatic-related intracranial pathology on computed tomography neuroimaging. Individuals also had to be age 16+ at the time of injury, receive acute medical care within 72 hours of injury at a TBIMS-affiliated trauma center, and inpatient rehabilitation at a designated TBIMS facility.

Control participants

Data from control subjects were collected through the Midlife Development in the United States (MIDUS) study, a nationally representative population survey investigating the association of behavioral, psychological, and social factors with age-related variations in health and well-being (21,22). Eligible MIDUS participants were non-institutionalized, English-speaking adults, living in the continental United States who are contacted through random digit dialing (21,22). For the present study, we pooled information for individuals with available health and cognitive data from two waves of MIDUS participants, the MIDUS II and Refresher cohorts. MIDUS II is a longitudinal follow-up and expansion of the original parent study, and the MIDUS Refresher study expanded enrollment of young and middle-aged adults to facilitate comparisons with other studies of mid- and later-life health. MIDUS II participants were enrolled from 2004 to 2006, and MIDUS Refresher participants were enrolled from 2011 to 2016. We excluded controls who answered "yes" to the MIDUS structured interview question, "Do you have history of serious head injury?" (n = 231). The total control sample pool eligible to be matched included 5,776 individuals (MIDUS II: n = 3,600; MIDUS Refresher: n = 2,176).

Measures

Cognitive data

We used the Brief Test of Adult Cognition by Telephone (BTACT) to measure cognitive function, having previously established its feasibility and utility in a TBI population (23). BTACT subtests are telephone adaptations of widely used neuropsychological tests and were selected to encompass a wide range of cognitive domains (24). BTACT subtests include: Rey Auditory Verbal Learning Test (RAVLT) immediate and delayed recall (25), Digits Backward (26), Category Fluency (27), Number Reasoning (28), and Backward Counting Task (28). We documented completion codes for all tests, including designating when a TBI participant was unable to complete a test due to severe cognitive deficits.

Health

We measured current health through questions on self-rated overall health and presence of selected health conditions. For self-rated overall health, cases and controls were asked a single question, "Compared to other people your age, how would you rate your overall health?" There were five possible answers: excellent, good, average, fair, and poor. This single question on self-rated health has been demonstrated in a meta-analysis as a strong predictor of mortality risk (29). For presence of individual health conditions, we asked participants, "In the past 12 months, have you experienced or been treated for any of the following?" We queried the same list of 18 health conditions in cases and controls. Crucially, these conditions could have been preexisting or new-onset conditions after TBI; therefore, we reported prevalence (not incidence) for each health condition.

Procedure

Data from the TBI cohort were collected via telephone one-year post-injury. We followed standard BTACT administration procedures as described in detail elsewhere (23). We designed TBIMS health questionnaires to exactly mirror the MIDUS study, thereby facilitating item-level data harmonization and direct comparisons between studies.

Participant consent and institutional review board approval

All TBI cases (or next-of-kin proxies) and controls consented for participation in this research. The institutional review board at each participating TBIMS NDB center approved the study. The IRB at the University of Wisconsin-Madison approved the MIDUS data collection study protocol.

Data availability

We obtained TBIMS NDB data used for this study through an internal request from the TBIMS National Data and Statistical Center (https://www.tbindsc.org/). We used publicly available MIDUS data in the current study (http://www.midus.wisc.edu/data/index.php).

Statistical analysis

BTACT scoring

We calculated standardized scores for each participant using pooled BTACT data from the MIDUS II and Refresher studies (30). These standardized scores reflect each participant's cognitive ability relative to that of similar persons (based on by decade of age, sex, and education (< vs. ≥ bachelor's degree) in the general population. Further details regarding these methods are provided elsewhere (30). For TBI cases unable to complete a neuropsychological subtest due to severity of their cognitive deficits, we assigned a score of zero (i.e., the lower bound) for that subtest, consistent with established methods (31). Completion codes for cognitive capacity were not available in the MIDUS study. The primary measure of cognitive performance, the BTACT cognitive composite score, was an average of six standardized subtests. We z-standardized cognitive composite scores, and higher scores represented more favorable cognitive performance.

To adjust for potential confounding by demographic factors, we matched each case to three controls without replacement based on age (± 5 years), sex, race (black, white, other), and education (< vs. ≥ bachelor's degree). Individual matching in a 1:3 ratio in a matched case–control study was done to remove potential confounding due to matching variables, and has been widely used in the matched case–control literature for increasing power to detect effects beyond a 1:1 case-to-control ratio (32–37). We specifically chose a 1:3 matching ratio because empirical evidence suggests a plateau of power and efficiency when matching greater than three controls to each case (38). Of note, the age range for the MIDUS study was 23–84, and age range of the TBIMS study was 16–92. For TBI cases who were outside the age range of MIDUS study (e.g. 16–22 or 85–92), we assigned an age of 23 and 84 for matching purposes, respectively, to increase likelihood of matching cases to three controls at the age extremes. All primary analyses were further adjusted for chronological age to adjust for any residual confounding by age between matched cases and controls.

For TBI-health condition associations, we used conditional logistic regression to calculate matched pairs ORs. We then evaluated whether the association between health and cognition varied by TBI case status. Specifically, we tested the interaction between TBI and self-rated overall health on cognitive composite scores using a linear mixed-effects model, and considered the matched pair set as a random effect. We treated self-rated health as a categorical variable (five categories, ranging from excellent to poor). We reported between and within group pairwise differences in BTACT composite scores by TBI and self-rated health (considering "average" self-rated health as a reference). We then tested the interaction between TBI and each individual health condition on cognitive composite scores using a linear mixed-effects model that considered the matched pair set as a random effect. To adjust for multiple statistical comparisons involving 18 individual conditions, we performed a Bonferroni correction by dividing a 5% α-threshold by 18 ($\alpha = 0.0028$), which was used as the statistical threshold in this study.

Sensitivity analysis

Per study inclusion criteria, TBI cases were required to be seen by health-care providers in the last 12 months. We cannot assume the same for controls in the MIDUS study; therefore, we conducted a sensitivity analysis restricting controls to include only those who reported ≥1 to the MIDUS question, "How many times you saw a doctor in the past 12 months about your physical health?" Using the restricted sample, we re-calculated prevalence of health conditions in the matched control sample.

Results

We summarized demographic characteristics of the study sample in Table 1. After matching, the cases and controls were balanced on age, sex, race, and education. We provided the flow diagram of participants for the analytic cohort in Figure 1. We removed 116 TBI cases with missing health information. Of the remaining 363 TBI cases, we matched 248 cases to three controls without replacement on age (± 5 years), sex, race (black, white, other), and education (< vs. ≥ bachelor's degree).

Prevalence of health conditions in TBI vs. control sample

We calculated the prevalence rates and 95% confidence intervals of health conditions in the TBI case and matched controls in Table 1. We reported the results of the conditional logistic regression models comparing odds of health conditions in TBI cases and matched controls (Table 2). After Bonferroni correction, the following health conditions were significantly positively associated with TBI: anxiety/depression/other emotional disorder (OR = 3.12, 95% CI: 2.20–4.43, $p < .001$), chronic sleeping problems (OR = 2.76, 95% CI: 1.86, 4.10, $p < .001$), and stroke (OR = 6.42, 95% CI: 2.93–14.10, $p < .001$). There were no health conditions with significant negative associations with TBI (e.g., conditions more common in controls than TBI cases).

Health and cognition associations

To test whether TBI and cognition associations vary by self-rated health, we ran a linear mixed effects model with matched pair set as a random effect. We presented between and within group pairwise differences in BTACT scores by TBI and self-rated health in Table 3. There was evidence of a significant interaction

Table 1. Demographic and health characteristics of cases and matched controls.

Variable	TBI cases (N = 248)	No TBI controls (N = 744)
Matched Demographic Characteristics		
Age€, Mean (SD)	55.7 (17.2)	55.9 (15.9)
Sex, Men (%)	166 (66.9%)	498 (66.9%)
Race, n (%)	180 (72.6%)	540 (72.6%)
White	29 (11.7%)	87 (11.7%)
Black	39 (15.7%)	117 (15.7%)
Other		
Education, n (%)	157 (63.3%)	471 (63.3%)
<BA	91 (36.7%)	273 (36.7%)
≥BA		
Health Characteristics		
Self-rated Health, n (%)	31 (12.7%)	123 (16.7%)
Excellent	108 (44.3%)	337 (45.7%)
Good	41 (16.8%)	182 (24.7%)
Average	38 (15.6%)	80 (10.9%)
Fair	26 (10.7%)	15 (2.0%)
Poor		
Health Conditions, prevalence rate (95% CI)		
Asthma, Bronchitis, or Emphysema	9.0% (5.4–12.6%)	13.0% (10.6–15.5%)
Arthritis, Rheumatism, or Other Bone or Joint	20.1% (15.0–25.1%)	23.8% (20.7–26.9%)
Sciatica, Lumbago, or Recurring Backache	20.9% (15.8–26.0%)	17.9% (15.1–20.6%)
Persistent skin trouble	8.2% (4.7–11.7%)	10.8% (8.5–13.0%)
Thyroid Disease	4.9% (2.2–7.7%)	6.5% (4.7–8.2%)
Recurring stomach trouble, Indigestion, or Diarrhea	17.6% (12.8–22.4%)	15.7% (13.1–18.3%)
Urinary or Bladder Problems	11.5% (7.4–15.5%)	14.0% (11.5–16.5%)
Gall Bladder Trouble	0.8% (0–2.0%)	2.0% (1.0–3.0%)
AIDS or HIV Infection	1.6% (0–3.2%)	0.4% (0–0.9%)
Lupus or other Autoimmune Disease	1.2% (0–2.6%)	1.1% (0.3–1.8%)
Persistent trouble with gums, mouth, or teeth	10.3% (6.4–14.1%)	10.6% (8.4–12.8%)
High Blood Pressure or Hypertension	40.3% (34.2–46.5%)	34.0% (30.6–37.4%)
Anxiety, Depression, or some other Emotional Disorder	33.6% (27.6–39.6%)	14.5% (12.0–17.1%)
Alcohol or Drug Problems	4.9% (2.2–7.6%)	2.0% (1.0–3.0%)
Migraine Headaches	10.7% (6.8–14.6%)	4.7% (3.2–6.2%)
Chronic sleeping problems	22.5% (17.3–27.8%)	9.5% (7.4–11.7%)
Diabetes or high blood sugar	15.3% (10.8–19.8%)	14.0% (11.5–16.5%)
Multiple Sclerosis, Epilepsy, or Other Neurological Disorders	4.1% (1.6–6.6%)	2.0% (1.0–3.0%)
Stroke	8.5% (5.0–12.0%)	1.6% (0.7–2.5%)
Ulcer, hernia or rupture, Piles or hemorrhoids	7.0% (3.8–10.2%)	11.2% (8.9–13.4%)
Swallowing Problems	8.2% (4.7–11.7%)	3.9% (2.5–5.3%)

€individuals aged 16–23 and 85–92 were included in this table with their actual age.

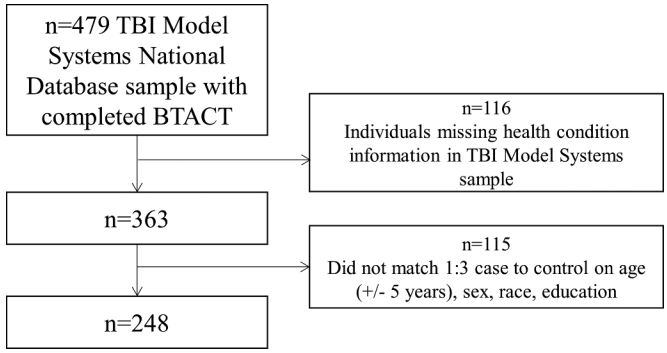

Figure 1. Flow diagram for analytic matched pairs sample. Three controls were matched to each case based on age (± 5 years), sex, race, and education. Cases age 16–22 and 85–92 were assigned age 23 and 84, respectively, to align with age range of control sample. This amounts to a more relaxed age criteria than ±5 years at the age extremes.

Table 2. Matched paired odds ratios for health conditions† among TBI and matched paired controls€.

Health Conditions	Odds Ratio§ (95% CI)	p-value
Asthma, Bronchitis, or Emphysema	0.66 (0.41, 1.07)	0.092
Arthritis, Rheumatism, or Other Bone or Joint	0.81 (0.55, 1.18)	0.266
Sciatica, Lumbago, or Recurring Backache	1.22 (0.85, 1.75)	0.279
Persistent skin trouble	0.75 (0.45, 1.27)	0.288
Thyroid Disease	0.73 (0.37, 1.43)	0.361
Recurring stomach trouble, Indigestion, or Diarrhea	1.17 (0.80, 1.71)	0.430
Urinary or Bladder Problems	0.81 (0.51, 1.28)	0.370
Persistent trouble with gums, mouth, or teeth	0.98 (0.61, 1.57)	0.932
High Blood Pressure or Hypertension	1.41 (1.02, 1.95)	0.040
Anxiety, Depression, or some other Emotional Disorder	3.12 (2.19, 4.43)	<0.0001*
Alcohol or Drug Problems	2.39 (1.10, 5.21)	0.028
Migraine Headaches	2.61 (1.50, 4.54)	0.0007*
Chronic sleeping problems	2.72 (1.83, 4.04)	<0.0001*
Diabetes or high blood sugar	1.14 (0.75, 1.74)	0.539
Multiple Sclerosis, Epilepsy, or Other Neurological Disorders	2.15 (0.96, 4.86)	0.065
Stroke	6.43 (2.93, 14.14)	<0.0001*
Ulcer, hernia or rupture, Piles or hemorrhoids	0.59 (0.34, 1.03)	0.065
Swallowing Problems	2.26 (1.25, 4.10)	0.007

€: Pairs matched on age (± 5 years), sex, race (white, black, other), and education (<BA, ≥BA)

§: Matched Pairs Odds Ratios and 95% CI were calculated using conditional logistic regression adjusted for age to account for any residual confounding by age; comparison is TBI vs. matched controls (reference)

*: indicates statistical significance at α = 0.0028

†: Gall bladder trouble, AIDS or HIV infection, and Lupus or other Autoimmune Disease were dropped from this table because there were fewer than 10 cases in the TBI group, therefore the estimates were unstable

between self-rated health and TBI ($p_{\text{interaction}} = 0.002$), thus the relationship between self-rated health and cognition significantly varied between TBI and controls. In general, cases with TBI had lower cognitive scores than controls, and the between-group differences were larger for those with poorer self-rated health. Within both the TBI group ($p < .001$) and no TBI control groups ($p = .002$) there was a significant relationship between self-rated health and cognition, such that lower ratings of self-rated health were associated with lower cognitive scores. However, when we inspected pairwise comparisons for self-rated health within each group, it highlighted that the trend between self-rated health and cognition was more pronounced among TBI cases relative to controls. For example, cases with TBI reporting "poor" self-rated health had 1.54 lower mean BTACT scores compared to cases with TBI reporting "average" self-rated health. In contrast, controls reporting "poor" self-rated health had 0.38 lower mean BTACT scores compared to controls reporting "average" self-

Table 3. Differences of least squares means estimates from linear mixed effects model of TBI and self-rated health associations with cognition.

	Difference[§] in BTACT score (SE)	Omnibus p-value
Within TBI cases (pairwise difference between rating *X* versus "average" self-rated health)		
Excellent-Average	0.82 (0.27)	<0.0001*
Good-Average	0.49 (0.21)	
Fair-Average	−0.06 (0.26)	
Poor-Average	−1.54 (0.30)	
Within no TBI controls (pairwise difference between rating *X* versus "average" self-rated health)		
Excellent-Average	0.33 (0.13)	0.002*
Good-Average	0.15 (0.11)	
Fair-Average	−0.24 (0.15)	
Poor-Average	−0.38 (0.30)	
Between group difference between TBI cases and controls for 5 level self-rated health		
Excellent (TBI-no TBI)	−0.44 (0.23)	0.002*
Good (TBI-no TBI)	−0.59 (0.12)	
Average (TBI-no TBI)	−0.93 (0.20)	
Fair (TBI-no TBI)	−0.75 (0.23)	
Poor (TBI-no TBI)	−2.09 (0.37)	

[§]: Difference calculated using a linear mixed effects regression model adjusted for matched pair as a random effect and adjusted for age to account for any residual confounding by age

*: indicates statistical significance at α = 0.0028

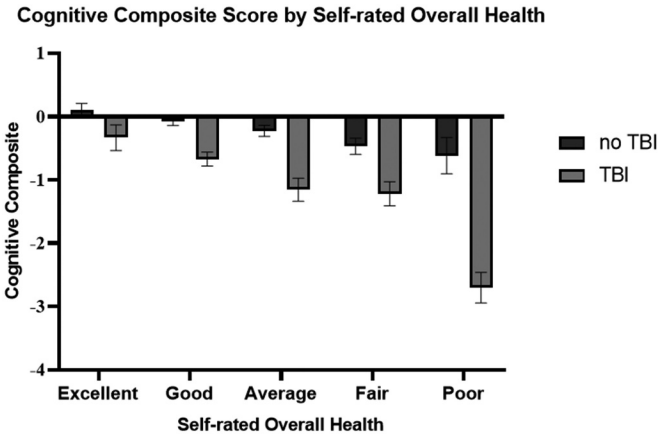

Figure 2. **Average Cognitive Composite Score by Self-Rated Overall Health and TBI case status**. We ran a linear mixed effects model, considering matched pairs as a random effect, and the interaction between TBI and self-rated health was tested. The model-based least square mean estimates by TBI and self-rated health category is presented here. The relationship between self-rated health and cognition is significant in TBI cases ($p < .0001$) and controls ($p = .0017$). The p-value for the TBI*condition interaction is 0.0021.

rated health. To illustrate the interaction, we graphed the model-based least square mean estimates by TBI and self-rated health category in Figure 2. The distributions of standardized BTACT composite scores for TBI cases and controls is provided for reference in **Supplemental Figure 1**.

Similarly, we tested interactions between individual health conditions and TBI on cognitive performance using a linear mixed model with a random effect for the matched pair set. After adjustment for multiple comparisons, there were no conditions that significantly modified the association between TBI and cognition (Table 4).

Sensitivity analyses

There were 181 individuals in the matched control sample with zero or unknown number of self-reported visits to the doctor in the last 12 months, leaving 563 controls reporting at least one visit to the doctor in the last 12 months for their physical health. We calculated the prevalence in the restricted control sample, and there were only modest changes in prevalence rates (**Supplemental Table 1**).

Discussion

Researchers now widely recognize TBI as a complex disease process associated with a number of secondary health conditions affecting long-term recovery (4,39–42). Limited studies, however, have directly compared disease burden among well-defined samples with TBI and population-based matched controls. Our current knowledge of the disease burden among persons living with TBI relative to the general population is confined by this limitation. The current study provides empirical evidence that selected neurobehavioral health conditions are more common among individuals with TBI as compared to similar uninjured adults in the general population.

Disproportionately high rates of health problems in the year following injury, irrespective of their causal link to TBI, contribute to the burden of disease experienced by TBI survivors. Current findings are consistent with previous reports that TBI can initiate or exacerbate neurobehavioral disorders, including depression, anxiety, headache/migraine, and sleep problems for some individuals (43). High prevalence rates after TBI, as well as their detrimental impact on TBI recovery, have been documented for mood disorders (44–46), stroke (47), headache/migraine (48), and poor sleep (49).

To our knowledge, ours is the first study documenting an interaction by TBI of the association between self-rated overall health and objective cognitive performance. Although it is well-known that on aggregate TBI cases have lower cognitive performance than controls, our finding indicates the relationship between TBI and cognition differs markedly at the lowest end of the continuum of self-rated overall health; in our study the difference in BTACT composite scores were over two standard deviations lower (−2.09) between TBI cases and controls who reported "poor" self-rated health. We also observed that the within group difference in cognitive performance between "poor" vs. "average" self-rated health was more pronounced in the TBI group relative to controls, suggesting the relationship between poorer self-rated health and worse cognition is stronger in TBI than controls. The presence of cognitive impairments that last more than one year is common following moderate-to-severe TBI (3,50), and has been documented to contribute to health management challenges in other clinical populations (51). There is little evidence to suggest that this

Table 4. Differences of least squares means estimates from linear mixed effects model of TBI and individual health condition associations with cognition.

	TBI cases[£]	no TBI controls[€]	
Health conditions	Difference in BTACT score with and without condition (SE)	Difference in BTACT score with and without condition (SE)	TBI*condition interaction p-value[§]
Asthma, Bronchitis, or Emphysema	0.19 (0.28)	−0.01 (0.13)	0.525
Arthritis, Rheumatism, or Other Bone or Joint	0.32 (0.20)	−0.11 (0.11)	0.053
Sciatica, Lumbago, or Recurring Backache	0.06 (0.19)	0.11 (0.11)	0.798
Persistent skin trouble	0.32 (0.28)	0.09 (0.14)	0.463
Thyroid Disease	0.76 (0.36)	0.35 (0.17)	0.303
Recurring stomach trouble, Indigestion, or Diarrhea	0.23 (0.21)	−0.28 (0.12)	0.034
Urinary or Bladder Problems	−0.32 (0.28)	−0.0003 (0.13)	0.300
Persistent trouble with gums, mouth, or teeth	−0.62 (0.27)	−0.16 (0.14)	0.129
High Blood Pressure or Hypertension	−0.27 (0.16)	−0.22 (0.10)	0.774
Anxiety, Depression, or some other Emotional Disorder	−0.18 (0.16)	−0.14 (0.12)	0.842
Alcohol or Drug Problems	−0.40 (0.36)	−0.50 (0.32)	0.830
Migraine Headaches	−0.72 (0.25)	−0.24 (0.20)	0.135
Chronic Sleeping Problems	−0.14 (0.19)	−0.08 (0.15)	0.797
Diabetes or high blood sugar	−0.16 (0.22)	−0.17 (0.13)	0.942
Multiple Sclerosis, Epilepsy, or Other Neuro Disorders	−0.78 (0.42)	−0.42 (0.30)	0.489
Stroke	−0.67 (0.28)	−0.43 (0.35)	0.599
Ulcer, hernia or rupture, Piles or hemorrhoids	0.07 (0.32)	0.04 (0.14)	0.912
Swallowing problems	−0.97 (0.28)	−0.17 (0.22)	0.025

[£]: pairwise model-based difference in BTACT score (SE) between TBI cases with condition and TBI cases without condition

[€]: pairwise model-based difference in BTACT score (SE) between controls with condition and controls without condition

[§]: TBI*health condition interaction p-value from linear mixed model (e.g., indicates if association between health condition and cognition vary by TBI status); linear mixed regression model adjusted for matched pair as a random effect and adjusted for age to account for any residual confounding by age

*: indicates statistical significance at α = 0.0028

association is impacted by inaccurate reporting among those with cognitive impairments. A recent study using the TBIMS NDB showed good-to-excellent test–retest reliability for the same questions about health conditions used in the present study (52). Studies have also documented positive congruence of self-report and physician ratings on health, with occurrences of incongruity toward overestimating healthiness (53).

In our study, TBI cases had higher prevalence of selected neurobehavioral conditions, and also worse cognitive scores than controls. However, unlike self-rated health, we did not find sufficient evidence of an interaction between presence of individual conditions and TBI on cognition. That is, observed differences in cognitive scores between those with TBI and controls did not meaningfully vary based on presence of individual health conditions. Notably, though not exceeding the significance threshold in our study, there was some suggestion that the presence of swallowing problems may negatively modify the association between TBI and cognitive performance, such that persons with both TBI and swallowing problems had even lower cognitive scores. Swallowing problems are a secondary neurological condition that can independently result in cognitive impairment (54), and future larger studies should further evaluate potential interactive effects of TBI and swallowing problems on cognitive performance.

There are limitations that should be considered when interpreting these findings. The age ranges in the MIDUS and TBIMS National Database studies were not perfectly aligned, and thus for matching purposes we modified ages of TBIMS participants at the extremes of the age range to align with the MIDUS sample in order to increase the likelihood of each case being matched to three controls. This change practically amounts to increasing our caliper distance beyond ±5 years at the age extremes. This more liberal criteria at the age extremes affords inclusion of TBI cases in our analysis at the oldest end of the age spectrum, who experts in the field have pointed out are often excluded from TBI research (55). We adjusted all analyses for chronological age to account for any residual confounding; therefore, this relaxing of the matching criteria is unlikely to affect the primary results. For those with TBI, it is not known whether health conditions were preexisting, co-occurring, or developed after the injury. Our matched case–control design allowed for direct comparison of disease prevalence relative to the general population; however, it precluded investigation into whether TBI causes these selected health conditions (or vice versa). Therefore, we cannot make any inferences in the current matched case–control study on relative risk of any health conditions after TBI that would have been possible in a prospective study. The list of health conditions studied was not comprehensive, and although we matched on several demographic factors, results may be impacted by unmeasured confounding. The TBIMS NDB is largely representative of the national population who receive inpatient rehabilitation for TBI (56), and findings may not generalize to individuals with TBI who did not receive specialized brain injury rehabilitation. We considered the possibility that health-care utilization differed across groups, but our sensitivity analysis that removed controls with no health-care encounter within the last 12 months did not meaningfully change crude prevalence rates. Completion codes for cognitive capacity were not available in the MIDUS study; therefore, we may have missed some controls with severe cognitive impairment not able to complete the BTACT. It is possible that case misclassification secondary to insensitive TBI ascertainment (57) in the MIDUS study biased findings toward the null, suggesting that differences reported here may be an underestimation.

Strengths of our study included the direct comparison of health and cognition between well-characterized TBI cases and matched population-based controls using harmonized measurement tools. Also, our analytic design by matching three controls to

each case based on demographic factors reduced confounding due to demographic factors. The TBI Model Systems has pioneered evidence supporting the notion of TBI as a chronic condition (4). Despite the several dozens of research articles in this area, the current study is the first TBI Model Systems NDB study to directly compare harmonized data to population-based controls.

Findings from the current study indicated that persons with TBI have a higher prevalence of selected neurobehavioral health problems relative to uninjured peers in the general population. The observed trend that poor self-rated health was associated with significantly lower objective cognitive performance among those with TBI compared to controls lends support to the notion that cognitive impairment may have adverse effects on perceived overall health following TBI. Adults living with long-term health and cognitive problems following TBI require tailored health management programs (58) that adapt evidence-based chronic disease management approaches (59) to accommodate TBI-related cognitive impairments.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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References

1. Coronado VG, McGuire LC, Sarmiento K, Bell J, Lionbarger MR, Jones CD, Geller AI, Khoury N, and Xu L . Trends in traumatic brain injury in the US and the public health response: 1995–2009. Journal of Safety Research. 2012;43(4):299–307.doi:10.1016/j.jsr.2012.08.011.
2. Arciniegas DB, Wortzel HS.Emotional and behavioral dyscontrol after traumatic brain injury. Psychiatric Clinics. 2014;37(1):31–53. doi:10.1016/j.psc.2013.12.001.
3. Dikmen SS, Corrigan JD, Levin HS, Machamer J, Stiers W, Weisskopf MG.Cognitive outcome following traumatic brain injury. The Journal of Head Trauma Rehabilitation. 2009;24(6):430–38.doi:10.1097/HTR.0b013e3181c133e9.
4. Corrigan JD, Hammond FM.Traumatic brain injury as a chronic health condition. Archives of Physical Medicine and Rehabilitation. 2013;94(6):1199–201.doi:10.1016/j.apmr.2013.01.023.
5. Masel BE, DeWitt DS.Traumatic brain injury: a disease process, not an event. Journal of Neurotrauma. 2010;27(8):1529–40. doi:10.1089/neu.2010.1358.
6. Mathias J, Alvaro P.Prevalence of sleep disturbances, disorders, and problems following traumatic brain injury: a meta-analysis. Sleep Medicine. 2012;13(7):898–905.doi:10.1016/j.sleep.2012.04.006.
7. Asikainen I, Kaste M, Sarna S.Early and late posttraumatic seizures in traumatic brain injury rehabilitation patients: brain injury factors causing late seizures and influence of seizures on long-term outcome. Epilepsia. 1999;40(5):584–89.doi:10.1111/j.1528-1157.1999.tb05560.x.
8. Ritter AC, Wagner AK, Fabio A, Pugh MJ, Walker WC, Szaflarski JP, Zafonte RD, Brown AW, Hammond FM, Bushnik T, et al. Incidence and risk factors of posttraumatic seizures following traumatic brain injury: a Traumatic Brain Injury Model Systems Study. Epilepsia. 2016;57(12):1968–77.doi:10.1111/epi.13582.
9. Lieberman SA, Oberoi AL, Gilkison CR, Masel BE, Urban RJ. Prevalence of neuroendocrine dysfunction in patients recovering from traumatic brain injury. The Journal of Clinical Endocrinology & Metabolism. 2001;86(6):2752–56.
10. Tanriverdi F, Senyurek H, Unluhizarci K, Selcuklu A, Casanueva FF, Kelestimur F.High risk of hypopituitarism after traumatic brain injury: a prospective investigation of anterior pituitary function in the acute phase and 12 months after trauma. The Journal of Clinical Endocrinology & Metabolism. 2006;91(6):2105–11.doi:10.1210/jc.2005-2476.
11. Albrecht JS, Barbour L, Abariga SA, Rao V, Perfetto EM.Risk of Depression after Traumatic Brain Injury in a Large National Sample. Journal of Neurotrauma. 2018;36(2):300–07.doi:10.1089/neu.2017.5608.
12. Bombardier CH.Rates of major depressive disorder and clinical outcomes following traumatic brain injury. Jama. 2010;303(19):1938–45.doi:10.1001/jama.2010.599.
13. Barnes DE, Kaup A, Kirby KA, Byers AL, Diaz-Arrastia R, Yaffe K. Traumatic brain injury and risk of dementia in older veterans. Neurology. 2014;83(4):312–19.doi:10.1212/WNL.0000000000000616.
14. Chosy EJ, Gross N, Meyer M, Liu C, Edland SD, Launer LJ, White LR . Brain Injury and Later-Life Cognitive Impairment and Neuropathology: the Honolulu-Asia Aging Study. Journal of Alzheimer's Disease. 2020;73(1) ;317–325.
15. Gardner RC, Burke JF, Nettiksimmons J, Kaup A, Barnes DE, Yaffe K.Dementia risk after traumatic brain injury vs nonbrain trauma: the role of age and severity. JAMA Neurology. 2014;71(12):1490–97.doi:10.1001/jamaneurol.2014.2668.
16. Gilsanz P, Albers K, Beeri MS, Karter AJ, Quesenberry CP, Whitmer RA.Traumatic brain injury associated with dementia risk among people with type 1 diabetes. Neurology. 2018;91(17):e1611–e8.doi:10.1212/WNL.0000000000006391.

17. Lee Y-K, Hou S-W, Lee C-C, Hsu C-Y, Huang Y-S, Su Y-C. Increased risk of dementia in patients with mild traumatic brain injury: a nationwide cohort study. PloS One. 2013;8:5.
18. Nordström A, Nordström P.Traumatic brain injury and the risk of dementia diagnosis: a nationwide cohort study. PLoS Medicine. 2018;15(1):1.doi:10.1371/journal.pmed.1002496.
19. Kumar RG, Boles JA, Wagner AK.Chronic inflammation after severe traumatic brain injury: characterization and associations with outcome at 6 and 12 months postinjury. Journal of Head Trauma Rehabilitation. 2015;30(6):369–81.doi:10.1097/HTR.0000000000000067.
20. Yi L, Shi S, Wang Y, Huang W, Xia Z-A, Xing Z, Peng W, and Wang Z . Serum metabolic profiling reveals altered metabolic pathways in patients with post-traumatic cognitive impairments. Scientific Reports. 2016;6(1):21320.doi:10.1038/srep21320.
21. Barry TR.The Midlife in the United States (MIDUS) series: a national longitudinal study of health and well-being. Open Health Data. 2014;2:1.
22. Ryff C, Almeida D, Ayanian J, Carr D, Cleary P, Coe C, Davidson RJ, Krueger RF, Lachman ME, Marks NF, et al. Midlife Development in the United States (MIDUS II), 2004–2006 [computer file]. Ann Arbor, MI: Interuniversity Consortium for Political and Social Research 2007.
23. Dams-O'Connor K, Sy KTL, Landau A, Bodien Y, Dikmen S, Felix ER, Giacino JT, Gibbons L, Hammond FM, Hart T, et al. The feasibility of telephone-administered cognitive testing in individuals 1 and 2 years after inpatient rehabilitation for traumatic brain injury. Journal of Neurotrauma. 2018;35(10):1138–45. doi:10.1089/neu.2017.5347.
24. Tun PA, Lachman ME.Telephone assessment of cognitive function in adulthood: the Brief Test of Adult Cognition by Telephone. Age and Ageing. 2006;35(6):629–32.doi:10.1093/ageing/afl095.
25. Rey A. The clinical examination in psychology. Paris: Presses Universitaires de France; 1964.
26. Wechsler IIID. WAIS-III administration and scoring manual. San Antonio, TX: The Psychological Corporation. 1997; 1997.
27. Baldo JV, Shimamura AP.Letter and category fluency in patients with frontal lobe lesions. Neuropsychology. 1998;12(2):259. doi:10.1037/0894-4105.12.2.259.
28. Lachman ME, Agrigoroaei S, Tun PA, Weaver SL.Monitoring cognitive functioning: psychometric properties of the Brief Test of Adult Cognition by Telephone. Assessment. 2014;21(4):404–17. doi:10.1177/1073191113508807.
29. DeSalvo KB, Bloser N, Reynolds K, He J, Muntner P.Mortality prediction with a single general self-rated health question: a meta-analysis. Journal of General Internal Medicine. 2006;21(3):267–75. doi:10.1111/j.1525-1497.2005.00291.x.
30. DiBlasio CASA, Kumar RG, Kennedy RE, Retnam R, Lachman ME, Novack TA, and Dams-O'Connor K.Research Letter: performance of the Brief Test of Adult Cognition by Telephone in a National Sample. Journal of Head Trauma Rehabilitation. 2021;36(4): E233 .
31. Bagiella E, Novack TA, Ansel B, Diaz-Arrastia R, Dikmen S, Hart T, and Temkin N . Measuring outcome in traumatic brain injury treatment trials: recommendations from the traumatic brain injury clinical trials network. The Journal of Head Trauma Rehabilitation. 2010;25(5):375.doi:10.1097/HTR.0b013e3181d27fe3.
32. Kaduma J, Seni J, Chuma C, Kirita R, Mujuni F, Mushi MF, van der Meer F, Mshana SE, et al. Urinary tract infections and preeclampsia among pregnant women attending two hospitals in Mwanza City, Tanzania: a 1: 2 Matched case-control study. BioMed Research International. 2019.
33. Morgan CD, Zuckerman SL, Lee YM, King L, Beaird S, Sills AK, and Solomon GS . Predictors of postconcussion syndrome after sports-related concussion in young athletes: a matched case-control study. Journal of Neurosurgery: Pediatrics. 2015;15(6):589–98.doi:10.3171/2014.10.PEDS14356.
34. Peleg AY, Husain S, Qureshi ZA, Silveira FP, Sarumi M, Shutt KA, Kwak EJ, and Paterson DL . Risk factors, clinical characteristics, and outcome of Nocardia infection in organ transplant recipients: a matched case-control study. Clinical Infectious Diseases. 2007;44 (10):1307–14.doi:10.1086/514340.
35. Qin P, Agerbo E, Mortensen PB.Suicide risk in relation to family history of completed suicide and psychiatric disorders: a nested case-control study based on longitudinal registers. The Lancet. 2002;360(9340):1126–30.doi:10.1016/S0140-6736(02)11197-4.
36. Whitney CG, Pilishvili T, Farley MM, Schaffner W, Craig AS, Lynfield R, Nyquist A-C, Gershman KA, Vazquez M, Bennett NM, et al. Effectiveness of seven-valent pneumococcal conjugate vaccine against invasive pneumococcal disease: a matched case-control study. The Lancet. 2006;368 (9546):1495–502.doi:10.1016/S0140-6736(06)69637-2.
37. Wright JK, Hayford K, Tran V, Al Kibria GM, Baqui A, Manajjir A, Mahmud A, Begum N, Siddiquee M, Kain KC, et al. Biomarkers of endothelial dysfunction predict sepsis mortality in young infants: a matched case-control study. BMC Pediatrics. 2018;18(1):1–12. doi:10.1186/s12887-018-1087-x.
38. Taylor JMG.Choosing the number of controls in a matched case-control study, some sample size, power and efficiency considerations. Statistics in Medicine. 1986;5(1):29–36. doi:10.1002/sim.4780050106.
39. Bombardier CH, Temkin NR, Machamer J, Dikmen SS.The natural history of drinking and alcohol-related problems after traumatic brain injury. Archives of Physical Medicine and Rehabilitation. 2003;84(2):185–91.doi:10.1053/apmr.2003.50002.
40. Kumar RG, Olsen J, Juengst SB, Dams-O'Connor K, O'Neil-Pirozzi TM, Hammond FM, and Wagner AK . Comorbid conditions among adults 50 years and older with traumatic brain injury: examining associations with demographics, healthcare utilization, institutionalization, and 1-year outcomes. The Journal of Head Trauma Rehabilitation. 2019;34(4):224–32.doi:10.1097/HTR.0000000000000470.
41. Malec JF, Ketchum JM, Hammond FM, Corrigan JD, Dams-O'Connor K, Hart T, Novack T, Dahdah M, Whiteneck GG, Bogner J, et al. Longitudinal effects of medical comorbidities on functional outcome and life satisfaction after traumatic brain injury: an individual growth curve analysis of NIDILRR traumatic brain injury model system data. The Journal of Head Trauma Rehabilitation. 2019;34(5):E24–E35.doi:10.1097/HTR.0000000000000459.
42. Weil ZM, Corrigan JD, Karelina K.Alcohol use disorder and traumatic brain injury. Alcohol Research: Current Reviews. 2018;39 (2):171.
43. Hammond FM, Corrigan JD, Ketchum JM, Malec JF, Dams-O'Connor K, Hart T, Novack TA, Bogner J, Dahdah MN, Whiteneck GG, et al. Prevalence of medical and psychiatric comorbidities following traumatic brain injury. The Journal of Head Trauma Rehabilitation. 2019;34(4):E1–E10.doi:10.1097/HTR.0000000000000465.
44. Hart T, Fann JR, Chervoneva I, Juengst SB, Rosenthal JA, Krellman JW, Dreer LE, and Kroenke K . Prevalence, risk factors, and correlates of anxiety at 1 year after moderate to severe traumatic brain injury. Archives of Physical Medicine and Rehabilitation. 2016;97(5):701–07.doi:10.1016/j.apmr.2015.08.436.
45. Juengst SB, Adams LM, Bogner JA, Arenth PM, O'Neil-Pirozzi TM, Dreer LE, Hart T, Bergquist TF, Bombardier CH, Dijkers MP, et al. Trajectories of life satisfaction after traumatic brain injury: influence of life roles, age, cognitive disability, and depressive symptoms. Rehabilitation Psychology. 2015;60(4):353. doi:10.1037/rep0000056.
46. Scholten AC, Haagsma JA, Cnossen MC, Olff M, Van Beeck EF, Polinder S.Prevalence of and risk factors for anxiety and depressive disorders after traumatic brain injury: a systematic review. Journal of Neurotrauma. 2016;33 (22):1969–94.doi:10.1089/neu.2015.4252.

47. Kowalski RG, Haarbauer-Krupa JK, Bell JM, Corrigan JD, Hammond FM, Torbey MT, Hofmann MC, Dams-O'Connor K, Miller AC, Whiteneck GG, et al. Acute ischemic stroke after moderate to severe traumatic brain injury: incidence and impact on outcome. Stroke. 2017;48(7):1802–09.doi:10.1161/STROKEAHA.117.017327.
48. Lucas S, Hoffman JM, Bell KR, Walker W, Dikmen S. Characterization of headache after traumatic brain injury. Cephalalgia. 2012;32(8):600–06.doi:10.1177/0333102412445224.
49. Nakase-Richardson R, Holcomb EM, Towns S, Kamper JE, Barnett SD, Sherer M, and Evans C . The relationship between sleep-wake cycle disturbance and trajectory of cognitive recovery during acute traumatic brain injury. Journal of Head Trauma Rehabilitation. 2016;31(2):108–16.doi:10.1097/HTR.0000000000000206.
50. Dikmen SS, Machamer JE, Winn HR, Temkin NR. Neuropsychological outcome at 1-year post head injury. Neuropsychology. 1995;9(1):80.doi:10.1037/0894-4105.9.1.80.
51. Ball J, Løchen M-L, Carrington MJ, Wiley JF, Stewart S.Mild cognitive impairment impacts health outcomes of patients with atrial fibrillation undergoing a disease management intervention. Open Heart. 2018;5(1):e000755.doi:10.1136/openhrt-2017-000755.
52. Bogner JA, Whiteneck GG, MacDonald J, Juengst SB, Brown AW, Philippus AM, Marwitz JH, Lengenfelder J, Mellick D, Arenth P, et al. Test-retest reliability of traumatic brain injury outcome measures: a traumatic brain injury model systems study. Journal of Head Trauma Rehabilitation. 2017;32(5):E1–E16.doi:10.1097/HTR.0000000000000291.
53. Maddox GL, Douglass EB.Self-assessment of health: a longitudinal study of elderly subjects. Journal of Health and Social Behavior. 1973;14(1):87–93.doi:10.2307/2136940.
54. Halper AS, Cherney LR, Cichowski K, Zhang M.Dysphagia after head trauma: the effect of cognitive-communicative impairments on functional outcomes. The Journal of Head Trauma Rehabilitation. 1999;14(5):486–96.doi:10.1097/00001199-199910000-00009.
55. Peters ME, and Gardner RC.Traumatic brain injury in older adults: do we need a different approach?. 2018;3(3):CNC56.
56. Corrigan JD, Cuthbert JP, Whiteneck GG, Dijkers MP, Coronado V, Heinemann AW, Harrison-Felix C, and Graham JE . Representativeness of the traumatic brain injury model systems national database. The Journal of Head Trauma Rehabilitation. 2012;27(6):391.doi:10.1097/HTR.0b013e318223 8cdd.
57. Dams-O'Connor K, Cantor JB, Brown M, Dijkers MP, Spielman LA, Gordon WA.Screening for traumatic brain injury: findings and public health implications. The Journal of Head Trauma Rehabilitation. 2014;29(6):479.doi:10.1097/HTR.0000000000000099.
58. Driver S, Reynolds M, Kramer K.Modifying an evidence-based lifestyle programme for individuals with traumatic brain injury. Brain Injury. 2017;31(12):1612–16.doi:10.1080/02699052.2017.1346286.
59. Group DPPR. The Diabetes Prevention Program (DPP): description of lifestyle intervention. Diabetes Care. 2002;25(12):2165–71. doi:10.2337/diacare.25.12.2165.