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Assessing the Relationship Between Chronic Pain and Cognition: A NIDILRR and VA TBI Model Systems Collaborative Project

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Abstract

Objective: To investigate the associations between current chronic pain and cognition and current chronic head pain and cognition in individuals with traumatic brain injury (TBI).

Setting: Community.

Participants: A total of 1762 participants from the TBI Model Systems who endorsed experiencing current chronic pain and who completed the Current Chronic Pain survey.

Design: Secondary analysis of a subset of data collected through a multi-site, cross-sectional observational cohort study.

The authors declare no conflicts of interests.

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Main Outcome Measures: Cognition as measured by the Brief Test of Adult Cognition by Telephone (BTACT).

Results: Individuals with TBI who reported current chronic pain exhibited lower cognitive performance compared to those who reported no pain. Among individuals who reported pain, greater pain intensity and pain interference were negatively associated with cognition, resulting in poorer cognitive performance. The negative association was even greater for individuals acknowledging chronic head pain compared to pain from other body locations.

Conclusion: The negative association between current chronic pain and cognition for individuals with TBI indicates the need to consider pain intensity and pain interference as factors possibly influencing cognitive ability.

Keywords

chronic pain; cognition; traumatic brain injury

INTRODUCTION

Chronic pain, defined as any pain that lasts for more than 3 months, has been shown to negatively impact cognition and memory in various patient populations.^{1,2} Melzack and Casey's early conceptual model of pain describes chronic pain as much broader than a sensory experience. Rather, pain is an experience characterized by a sensorially, physically, and emotionally disruptive phenomenon that influences individual perception, motivation, and affect. Pain models hypothesize that chronic pain negatively impacts attention, decision-making, and cognitive flexibility,³ and recent literature supports that, in otherwise healthy individuals, chronic pain significantly correlates with attention, memory, learning, and executive function deficits.^{3,4} In individuals with traumatic brain injury (TBI), studies indicate that those who report current chronic pain 1–30 years after injury also report significantly worse physical and cognitive function outcomes,⁵ which suggests that these individuals are impacted by pain for years after injury and likely endure the symptoms with limited medical support.⁶

TBI itself is associated with cognitive changes, motor deficits, and sensory abnormalities; however, there is evidence that over 50% of persons with moderate-to-severe TBI also develop debilitating chronic pain that may additively affect long-term daily function and health-related quality of life.⁷ Headache is one of the most common pain locations after TBI, with 71% of individuals reporting it 1 year post-injury and 33% reporting it 5 years post-injury.⁸ Further, migraine-like symptoms are often reported by individuals with TBI who experience chronic head pain,⁹ and migraine pain is associated with poorer verbal comprehension, complex attention, immediate memory, and spatial cognition.¹⁰ Musculoskeletal pain, neuropathic pain, and pain related to mobility impairment are also common after TBI and negatively impact quality of life.¹¹

Thus, individuals with moderate-to-severe TBI experience high rates of chronic cognitive deficits and chronic pain, both of which negatively impact functional outcomes. Emerging evidence suggests a complex and multifaceted relationship between pain and cognitive

function after TBI that, to date, is not well understood.^{12,13} Consequently, it is difficult to develop or identify existing interventions to treat pain and/or cognitive deficits after TBI. To address this knowledge gap in individuals with moderate-to-severe TBI, our study objective is twofold: to examine the associations between (1) cognition and features of chronic pain, including pain intensity and pain interference; and (2) cognition and chronic head pain.

METHODS

Design

This study is a secondary analysis of a project entitled, “The Characterization and Treatment of Chronic Pain after Moderate to Severe Traumatic Brain Injury” (referred to as the Chronic Pain Study or CPS), a multicenter, cross-sectional, observational cohort study of individuals with moderate-to-severe TBI participating in the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR) Traumatic Brain Injury Model Systems (TBIMS).¹⁴ TBIMS is a national longitudinal study that tracks outcomes after TBI across the lifespan to inform clinical practices and advance standards of care.

Participants

The inclusion criteria of the CPS were also used for this study. Participants were enrolled in the TBIMS at 1 of the 18 participating rehabilitation centers, including one Veterans Health Administration TBIMS center, and completed at least one routine follow-up interview at any of the post-injury time points occurring at years 1, 2, 5, or at 5-year intervals thereafter. TBIMS participants who required a proxy to complete the scheduled follow-up or who were non-English speaking were excluded. The additional CPS inclusion criteria have been previously published.⁵ The CPS sample is comprised of 3804 participants; 1762 with current chronic pain, 525 with past chronic pain, and 1517 with no pain. Small effect-size differences in sociodemographic (eg, age, sex, race, employment status, military status, living situation) and injury characteristics (injury cause and post-traumatic amnesia [PTA]) were previously reported, suggesting little clinical difference between these groups. These results can be found in Supplemental Digital Content (available at: <http://links.lww.com/JHTR/A924>).

The final sample for this analysis objective part (1) included 1762 CPS participants who reported having current chronic pain. Current chronic pain was defined as, “Persistent or recurring pain that lasts longer than 3 months. It includes headaches or pain anywhere in the body which occurs on more than half of the days over a 3-month period.”⁵ The sample for objective part (2) included 828 of the current chronic pain participants who also reported experiencing head pain, such as headache or migraine. CPS participants with head pain responded to a series of separate headache-related questions¹⁵ with the goal of gaining a heightened understanding of the relationship between head pain/migraines and functional disability.

Procedure

During TBIMS follow-up interviews, participants were educated about the CPS, asked about their willingness to participate, and verbally consented if willing. Participants were

then provided the standard definition of chronic pain as stated above. They were then asked, *Are you experiencing chronic pain?* If they endorsed current chronic pain, the participant completed the *Current Chronic Pain* survey. Participants had an 8-week window to complete their assigned survey. The survey platform used was based on personal preference: telephone, mail, or an emailed survey link.

Measures

Data for this analysis were collected from the TBIMS database and the CPS. This survey consists of a variety of previously validated pain measures, including measures for headache which are described in Pain characteristics below.

Demographics. Sociodemographic variables included age, sex, race/ethnicity, marital status, level of education, employment status, body mass index (BMI), past mental health interventions, controlled substance use, and medication/opioid use. Controlled substance use is defined as a person having either taken illicit drugs in the past 12 months, consumed 5 or more alcoholic drinks in one sitting within the past month, or consumed greater than 14 drinks in a week for males or 7 drinks for females in the past month. Opioid use was defined as having ever used prescribed opioid medication in the past or having used prescribed opioid medication in the past year that was not prescribed. Injury characteristics included injury etiology, time since injury, and days of PTA, (injury severity). Functional outcomes like communication ability, motor response, cognitive ability to complete daily living activities, and employability were measured using the Disability Rating Scale.¹⁶

Cognition. Cognition was assessed using the Brief Test of Adult Cognition by Telephone (BTACT).¹⁷ The BTACT is a 15- to 20-minute brief measure of global cognitive function validated for telephone administration. The BTACT was administered to participants within 8 weeks prior to completing the CPS. The subscales include episodic verbal memory, working memory, verbal fluency, inductive reasoning, processing speed. For analyses, the three Midlife in the United States (MIDUS)^{18,19} standardized BTACT composite scores²⁰ were selected as the primary outcomes. The MIDUS BTACT scores include an overall composite score and two subscales for episodic verbal memory and executive functioning. All scores were standardized based on the participant's age, sex, and education level.

Pain characteristics. The Brief Pain Inventory (BPI) was used to collect data regarding pain location, intensity, and interference. The BPI assesses the severity of pain, impact of pain on daily function, location of pain, pain interference, and pain relief. Responses are made on a Likert scale of 0 (no pain or interference) to 10 (pain as bad as you can imagine or completely interferes).²¹

The Headache Impact Test (HIT-6) is a self-report measure used to assess the impact of headaches on daily function. The items cover severe pain, pain-related functional limitation, tiredness, feelings of irritation, and concentration difficulties. Responses are made on a 5-point Likert scale of never to always.²² The HIT-6 was only asked of those participants who reported head pain.

The Lucas and colleagues' headache characterization strategy²³ was used to classify headache type. Headaches were classified into migraine, probable migraine, tension-type headache, and cervicogenic headache (a symptom-defined secondary headache). If head pain did not fit into these categories, it was characterized as unclassifiable. For this analysis, a participant was considered to have "migraine features" if they were classified into migraine or probable migraine. Decisions for headache classification were made based on the responses to the headache questionnaire, International Classification of Headache Disorders, 2nd edition (ICHD-2) criteria, and expert review using a decision tree. A headache was classified as a migraine if it was reported as moderate-to-severe and met at least two of the following criteria: (1) The headache had a significant disabling impact; (2) The headache was unilateral; (3) The headache was throbbing/pulsating; (4) The headache was worsened by movement or physical activity.

Psychosocial outcomes. Sleep data were collected using the Pittsburgh Sleep Quality Index (PSQI).²⁴ The PSQI is a self-report measure designed to measure overall sleep quality that is a combination of open-ended and Likert scale questions. Respondents indicate how frequently they experience sleep difficulties and rate their overall sleep quality. The PSQI total score ranged from 0 to 21 with higher scores indicating worse sleep quality.

Post-Traumatic Stress Disorder (PTSD) symptomology was assessed using the PTSD Checklist for DSM-5 (PCL-5).^{25,26} The PCL-5 is a 20-item self-report measure that assesses 20 DSM-5 symptoms of PTSD. Responses are made on a Likert scale of 0 (not at all) to 4 (extremely). The PCL-5 ranged from 0 to 80 with higher scores indicating worse PTSD symptomology.

Depression severity was measured using the Patient Health Questionnaire (PHQ-9),²⁷ a self-report measure of depression symptoms. Respondents indicate how often they experience symptoms of depression from 0 (not at all) to 3 (nearly every day). PHQ-9 scores range from 0 to 27 with higher scores indicating worse depression symptoms.

Anxiety severity was measured by the Generalized Anxiety Disorder-7 (GAD-7),²⁸ a self-report measure of anxiety symptoms. Respondents indicate how often they experience symptoms of anxiety from 0 (not at all) to 3 (nearly every day). GAD-7 scores range from 0 to 21 with higher scores indicating worse anxiety.

Primary insurance. The primary insurance provider was hierarchically ordered as Veterans Affairs (VA), private insurance, Medicare, and Medicaid. If participants reported two or more coverage sources, their primary insurance source was determined based on this order.

Analytic plan

All statistical analyses were performed using SAS v9.4²⁹ assuming a significance level of 0.05 unless otherwise stated. Sample characteristics included all demographic, injury-related, psychosocial, cognitive, and pain items. The continuous variables were summarized using means and standard deviations (SDs) and frequency counts and percentages were used for the categorical variables. Medians and interquartile ranges described any skewed

variables. All characteristics were summarized for both the current chronic pain and current chronic head pain samples.

BTACT scores were compared between the current chronic pain sample and those participants without chronic pain using two-sided *t*-tests and Cohen's *D* effect sizes (ESs). Associations between pain and cognition were assessed for the current chronic pain sample using correlations, ESs, and both unadjusted and adjusted linear regression models. All three BTACT scores were used as cognitive outcomes, and pain was represented by the combination of mean BPI pain intensity and mean BPI pain interference, and head pain location (Y/N).

All adjusted models controlled for age, level of education, GAD-7, PSQI, PTA duration, primary insurance provider, and opioid use. Due to the high correlations between the GAD-7, PHQ-9, and PCL-5, only one of these psychosocial variables could be included within the multivariate models to avoid multicollinearity. Preliminary analyses revealed that the GAD-7 had the strongest association with cognition within our sample and therefore was included in our models. For analytic reasons, PTA duration was normalized using a log-transformation and a Bonferroni correction was assessed when necessary. All regression model results were summarized using mean estimate change, a 95% confidence interval, and significance levels. ESs were calculated using model estimates divided by the root mean square error of the respective model.

For those with current chronic head pain, the associations between pain and cognition were analyzed using the same methods previously described. All BTACT scores were used as outcomes, and the HIT-6 represented head pain. Consistent covariates were controlled for in adjusted models with the addition of migraine classification.

RESULTS

Sample description

The current chronic pain sample consisted of 1762 participants with an average age of 46 years. The majority were male (73%), white (66%), had greater than a high school diploma (60%), and had private insurance (37%). The sample has a median of 5.4 years for time since injury and PTA duration ranged from 0 to 441 days with a median of 16 days. Chronic head pain was reported in 47% of the sample, and the majority reported the use of opioids (60%), having a vehicular etiology (53%), no use of controlled substances (70%), and no pre-injury history of mental health treatment (69%). The majority of participants with current chronic head pain reported having migraine features (81%).

Median scores for depression and anxiety were 7 and 5, respectively. Average sleep quality scores were 8.6 and median PTSD scores were 19. Average cognitive outcomes were below the mean standardized score of 0. The BTACT composite score had a mean of -0.5 and ranged from -3.4 to 1.6. The average BTACT executive function was -0.4 with a range of -3.6 to 2.3, and the average BTACT episodic verbal memory was -0.7 with a range of -3.0 to 3.4. Table 1 summarizes all characteristics for both the current chronic pain and the current chronic head pain samples.

Current chronic pain associations with cognition

Cognitive scores were significantly worse for those with current chronic pain compared to those with no pain. The unadjusted associations were statistically significant for all pain predictors with all cognitive outcomes and small ESs were identified in both analyses. BTACT scores decreased on average between 0.10 and 0.14 SDs for every one-point increase in a participant's pain intensity. Increases in pain interference demonstrated a similar relationship with cognitive scores decreasing between 0.07 and 0.10 SDs. Those participants who reported current chronic head pain also showed worse cognitive outcomes compared to those who did not. See Tables 2 and 3 respectively for results.

After adjusting for relevant characteristics that could impact cognition, significant relationships remained between all pain predictors and the BTACT composite and executive functioning scores. Pain intensity was the only variable found to significantly impact BTACT episodic verbal memory. Pain intensity and interference negatively impacted each of the cognitive outcomes and those with current chronic head pain had worse BTACT scores. All adjusted associations between pain and cognition revealed small ESs and correlations.

Controlling for pain intensity and pain interference, significant relationships were also seen with injury severity, level of education, primary insurance provider, opioid use, age, and anxiety. Participants with longer durations in PTA, less education, and those who did not report opioid use demonstrated lower cognitive scores for all outcomes. Participants with either Medicare or Medicaid as their primary insurance provider also had worse cognitive scores for each outcome when compared to those with private insurance. Increased age was associated with better cognition (BTACT composite scores) while anxiety was negatively related to episodic verbal memory.

Similar associations were seen in the adjusted models controlling for head pain location. Injury severity, level of education, and insurance provider were significantly related to all three cognitive outcomes. Lack of opioid use and anxiety were negatively related to BTACT composite and episodic verbal memory scores and those who reported poorer sleep quality demonstrated significantly worse cognition (BTACT composite and executive function scores). The full results for all adjusted models with the current chronic pain sample are shown in Table 4.

Chronic head pain associations with cognition

Unadjusted model results revealed a negative association between chronic head pain and cognition. For every one-point increase in the HIT-6, all BTACT scores decreased by 0.02 SDs on average for those who reported current chronic head pain. The HIT-6 maintained a significant relationship with the BTACT composite and executive function scores after adjusting for additional model covariates. All unadjusted and adjusted associations between the HIT-6 and cognition revealed small ESs and correlations. Significant associations were also seen between all BTACT outcomes and insurance provider; injury severity was significantly associated with BTACT composite and episodic verbal memory; and level of education was significantly associated with BTACT composite and executive functioning while opioid use was significantly associated with episodic verbal memory. Post hoc

analysis evaluating pain intensity, pain interference, and head pain revealed no confounding impact with the model results. The complete unadjusted and adjusted model results for the current chronic head pain sample are described in Tables 3 and 4.

DISCUSSION

This study examined the association between chronic pain and cognition within the largest prospective cohort of persons surviving moderate-to-severe TBI to date. Individuals who reported chronic pain had worse cognitive scores compared to individuals who denied pain ($n = 1517$). Greater pain severity (intensity and interference) was associated with poorer cognition. Additionally, in an unadjusted comparison, individuals with head pain showed worse cognitive outcomes compared to those who denied head pain. Significant associations were observed for PTA duration, primary insurance provider, and opioid use across all three BTACT outcomes. The association with PTA duration was expected given that is the most robust clinical measure of TBI severity and overall functional prognosis,^{29–31} and individuals in this sample who took longer to emerge from PTA had worse cognition. Worse cognition was also found for non-opioid users when compared to opioid users. Similar covariate associations were observed for our subgroup analyses on head location pain. Worse cognition for non-opioid users is difficult to reconcile with the literature, but may represent selection bias for those prescribed opioids, or an avoidance of opioids by individuals with limited cognitive ability, substance abuse histories, or mental health conditions. Data collection included medications prescribed regardless of long-term scheduled daily use or occasional as-needed use, so this does not provide insights into actual use patterns.

Individuals with private insurance scored higher on BTACT than those with Medicare or Medicaid which is consistent with prior studies of long-term cognitive and physical functional outcomes in the TBIMS cohort.^{32–34} Though increased age relating to better cognition was a surprising result, it may be associated with higher levels of education reported by this sample and warrants further investigation. Anxiety was also found to negatively impact BTACT composite and episodic verbal memory scores, but not scores of executive function.

All of the above relationships remained significant after adjusting for other factors in multivariable regression analyses. Although associations were statistically significant, standardized ESs were found to be small indicating these differences in cognition may be of limited clinical significance. However, there is no literature yet to guide clinical interpretation of BTACT scores. Overall, these findings provide preliminary evidence for the impact of comorbid pain on cognition following TBI.^{35–37} As expected, the mean and median BTACT scores for our sample with chronic pain were below those found in normative data as full cognitive recovery after moderate-to-severe TBI is atypical.^{35–37} Our findings that individuals without pain after TBI had better cognitive scores than those who reported pain, had greater pain intensity or greater perceived effects of pain, or had greater impact of headache on daily life is consistent with general population data.^{3,4} The study data further indicate that individuals with TBI and chronic pain whose pain is located in the head are at greatest risk for reduced cognition. This suggests that scores on cognitive

testing derived from individuals with TBI may not accurately reflect true cognitive ability when chronic pain is present, especially with higher pain intensity and/or head pain. Our findings support a holistic approach to clinical care, with the inclusion of pain screening and treatment or referral pathways for individuals with TBI and cognitive difficulties. Individuals with TBI and chronic pain should be counseled, along with their families, that pain may be contributing to their day-to-day cognitive symptoms, difficulties, or challenges. Cognitive-behavioral therapy may be beneficial in this regard, along with other potential behavioral strategies for minimizing the pain experience, such as biofeedback, controlled breathing, or meditation.³⁸

LIMITATIONS

Several limitations may be considered for this analysis. First, the sample analyzed may not represent all individuals with TBI due to the exclusion criteria for the CPS.⁵ The results may not apply to those who experienced past chronic pain with resolution as the pain sample included only those who endorsed current chronic pain. Further, the use of self-report surveys is inherently biased as respondents may be prone to socially desirable responses, may not understand the questions, may be untruthful, may be influenced by the proctor, or may not be adept at using the survey delivery platform.³⁹ Those who completed the survey over the phone (79% of respondents who reported current pain; 77% of respondents who reported current head pain) may have disclosed more or less information compared to those who completed the survey online or on paper. Analytically, all sample sizes for our study were quite large and may have resulted in inflated significance levels. All model results should be interpreted cautiously with an emphasis on the ESs as these are standardized measures of change. Clinical interpretation of BTACT scores has not yet been established which may limit clinical translation. Lastly, given the nature of survey-based data collection, the relationship between TBI, chronic pain, and cognition beyond the Likert-scale responses could not be explored, and further research in this area is warranted. A future study that employs a mixed-methods approach may further elucidate the complex relationship between cognitive deficits and chronic pain after TBI.

CONCLUSION

In conclusion, this study suggests that chronic pain negatively impacts cognition after TBI above and beyond other factors including TBI severity, especially among individuals who experience greater pain intensity and/or head located pain. Future studies of cognition after TBI should include pain intensity and location as possible mediating or moderating factors. Clinically, these findings suggest that pain management should be addressed as part of a holistic approach to cognitive rehabilitation after TBI.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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TABLE 1
Summary of the demographic, injury-related, psychosocial, cognitive, and pain characteristics for the study samples

	Current chronic pain N = 1762			Current chronic head pain N = 828		
	N	Mean (SD)/Median (IQR)		N	Mean (SD)/Median (IQR)	
BTACT composite score	1217	-0.5 (0.8)		526	-0.6 (0.8)	
BTACT executive functioning	1230	-0.4 (0.8)		530	-0.5 (0.8)	
BTACT episodic verbal memory	1269	-0.7 (0.9)		548	-0.9 (0.9)	
Mean BPI pain intensity	1741	4.8 (1.9)		822	5.1 (1.8)	
Mean BPI pain interference	1727	4.4 (2.5)		814	5.0 (2.5)	
HIT-6 total score	-	-		805	62.3 (8.3)	
Age (years)	1761	46.4 (15.1)		828	43.3 (13.2)	
BMI	1465	27.8 (5.9)		625	28.2 (6.1)	
Time since injury (years)	1762	5.4 (2.1–14.6)		828	5.5 (2.1–14.6)	
PTA duration (days)	1704	16 (3–31)		799	13 (1–29)	
DRS	1670	2 (1–4)		788	3 (1–4)	
PHQ-9 total score	1667	7 (3–12)		785	9 (5–14)	
GAD-7 total score	1671	5 (2–10)		794	7 (3–13)	
PCL-5 total score	1684	19 (8–34)		784	27 (14–41)	
PSQI total score	1670	8.6 (4.6)		774	10.0 (4.7)	
	N	%		N	%	
Current chronic head pain						
No	922	52.7%		-	-	
Yes	828	47.3%		-	-	
(Missing)	12			-		
Migraine classification						
Migraine features	-	-		656	81.0%	
Migraine non-features	-	-		154	19.0%	
(Missing)	-			18		
Sex						
Female	478	27.1%		238	28.7%	
Male	1284	72.9%		590	71.3%	
Race/ethnicity						

White	1149	65.7%	494	60.2%
Black	299	17.1%	161	19.6%
Hispanic	209	11.9%	122	14.9%
Other	92	5.3%	44	5.4%
(Missing)	13		7	
Marital status				
Single (never married)	619	35.2%	287	34.7%
Married	676	38.4%	332	40.1%
No longer married	464	26.4%	208	25.2%
(Missing)	3		1	
Highest level of education				
Less than HS diploma	285	16.2%	142	17.2%
HS diploma	422	24.0%	194	23.5%
Some college	654	37.2%	316	38.3%
Bachelor degree or greater	396	22.5%	174	21.1%
(Missing)	5		2	
Employment status				
Employed/Student	687	39.1%	340	41.2%
Unemployed	258	14.7%	135	16.4%
Retired	719	40.9%	304	36.8%
Other	92	5.2%	46	5.6%
(Missing)	6		3	
Injury etiology				
Vehicular	939	53.4%	389	47.0%
Fall	357	20.3%	157	19.0%
Violence	263	15.0%	184	22.2%
Other	200	11.4%	97	11.7%
(Missing)	3		1	
Primary insurance provider				
Private	641	37.2%	274	33.8%
Medicare	519	30.1%	207	25.5%
Medicaid	309	17.9%	169	20.8%

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Veterans affairs (Missing)	256 37	14.8%	161 17	19.9%
Opioid use				
No	690	40.0%	320	39.4%
Yes	1037	60.0%	492	60.6%
(Missing)	35		16	
Use of controlled substances				
No	1148	69.5%	549	70.7%
Yes	504	30.5%	228	29.3%
(Missing)	110		51	
Pre-injury mental health treatment				
No	909	69.4%	426	67.1%
Yes	401	30.6%	209	32.9%
(Missing)	452		193	

Abbreviations: BMI: body mass index; BPI: Brief Pain Inventory; BTACT: Brief Test of Adult Cognition by Telephone; DRS: Disability Rating Score; GAD-7: General Anxiety Disorder-7; HIT-6: Headache Impact Test-6; HS: High School; IQR: Interquartile range; PCL-5: Post-Traumatic Stress Disorder (PTSD) Checklist for DSM-5; PHQ-9: Patient Health Questionnaire-9; PSQI: Pittsburgh Sleep Quality Index; PTA: Posttraumatic Amnesia; SD: Standard Deviation.

TABLE 2
Comparison of MIDUS BTACT scores between participants with current chronic pain and participants with no chronic pain

	Current chronic pain, N = 1762 Mean (SD)	No chronic pain, N = 1517 Mean (SD)	ES	P-value
MIDUS BTACT composite score	-0.50 (0.75)	-0.38 (0.72)	0.16	<.001
MIDUS BTACT executive function	-0.39 (0.82)	-0.27 (0.78)	0.15	<.001
MIDUS BTACT episodic verbal memory	-0.73 (0.93)	-0.62 (0.95)	0.12	.003

Abbreviations: BTACT, Brief Test of Adult Cognition by Telephone; ES, effect size; SD, standard deviation.

TABLE 3

Unadjusted linear regression model results

	N	Estimate	95% CI	P-value	ES	Correlation
BTACT composite score						
Mean BPI pain intensity	1201	-0.12	(-0.15,-0.10)	<.001	0.18	-0.33
Mean BPI pain interference	1195	-0.09	(-0.11,-0.07)	<.001	0.13	-0.31
Head pain (no vs yes)	1208	0.21	(0.13, 0.29)	<.001	0.28	-
HIT-6 ^a	510	-0.02	(-0.03,-0.01)	<.001	0.03	-0.22
BTACT executive functioning						
Mean BPI pain intensity	1214	-0.14	(-0.16,-0.12)	<.001	0.18	-0.33
Mean BPI pain interference	1208	-0.10	(-0.11,-0.08)	<.001	0.13	-0.30
Head pain (No vs Yes)	1221	0.22	(0.12, 0.31)	<.001	0.27	-
HIT-6 ^a	513	-0.02	(-0.03,-0.01)	<.001	0.03	-0.22
BTACT episodic verbal memory						
Mean BPI pain intensity	1250	-0.10	(-0.13,-0.08)	<.001	0.11	-0.21
Mean BPI Pain Interference	1244	-0.07	(-0.09,-0.05)	<.001	0.08	-0.20
Head pain (no vs yes)	1258	0.21	(0.11, 0.32)	<.001	0.23	-
HIT-6 ^a	531	-0.01	(-0.02,-0.003)	.009	0.01	-0.11

Abbreviations: BTACT, Brief Test of Adult Cognition by Telephone; CI, confidence interval; ES, effect size; BPI: Brief Pain Inventory; HIT: Headache Impact Test.

^aCurrent chronic head pain participants only.

TABLE 4

Adjusted linear regression model results

	BTACT composite score (N = 987)		BTACT executive functioning (N = 996)		BTACT episodic verbal memory (N = 1027)	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Pain intensity and interference						
Mean BPI pain intensity	-0.06	(-0.09, -0.03) ^a	-0.07	(-0.10, -0.04) ^a	-0.04	(-0.08, -0.01) ^a
Mean BPI pain interference	-0.04	(-0.06, -0.01) ^a	-0.04	(-0.07, -0.1) ^a	-0.03	(-0.06, 0.002)
PTA duration (days [log])	-0.08	(-0.12, -0.04) ^a	-0.06	(-0.10, -0.02) ^a	-0.11	(-0.16, -0.06) ^a
Age (10 years)	0.03	(0.001, 0.06) ^a	0.03	(-0.01, 0.06)	0.04	(-0.003, 0.08)
Highest level of education						
Bachelor or greater vs some college	-0.16	(-0.28, -0.03) ^b	-0.24	(-0.37, -0.11) ^b	0.05	(-0.11, 0.21)
Bachelor or greater vs high school Diploma	0.01	(-0.12, 0.14)	-0.03	(-0.17, 0.11)	0.10	(-0.07, 0.28)
Bachelor or greater vs less than high school	0.29	(0.14, 0.44) ^b	0.31	(0.15, 0.47) ^b	0.27	(0.07, 0.47) ^b
Some college vs high school diploma	0.17	(0.06, 0.28) ^b	0.21	(0.10, 0.33) ^b	0.05	(-0.09, 0.19)
Some college vs less than high school	0.45	(0.33, 0.57) ^b	0.55	(0.41, 0.68) ^b	0.22	(0.05, 0.38) ^b
High School diploma vs less than high school	0.28	(0.16, 0.41) ^b	0.34	(0.20, 0.47) ^b	0.17	(-0.001, 0.33)
Insurance provider						
Private vs medicare	0.28	(0.17, 0.38) ^b	0.27	(0.16, 0.38) ^b	0.28	(0.15, 0.42) ^b
Private vs medicaid	0.26	(0.15, 0.37) ^b	0.24	(0.12, 0.37) ^b	0.31	(0.16, 0.46) ^b
Private vs VA	0.06	(-0.20, 0.31)	0.08	(-0.19, 0.36)	-0.04	(-0.37, 0.30)
Medicare vs medicaid	-0.02	(-0.14, 0.10)	-0.03	(-0.16, 0.10)	0.02	(-0.13, 0.18)
Medicare vs VA	-0.22	(-0.48, 0.03)	-0.19	(-0.46, 0.08)	-0.32	(-0.65, 0.01)
Medicaid vs VA	-0.20	(-0.47, 0.06)	-0.16	(-0.44, 0.12)	-0.35	(-0.69, -0.004)
Opioid use (no vs yes)	-0.12	(-0.21, -0.04) ^a	-0.11	(-0.20, -0.01) ^a	-0.16	(-0.28, -0.05) ^a
GAD-7 total score	-0.01	(-0.02, 0.002)	-0.002	(-0.01, 0.01)	-0.01	(-0.02, -0.002) ^a
PSQI total score	-0.001	(-0.01, 0.01)	-0.004	(-0.02, 0.01)	0.01	(-0.01, 0.02)
Head pain						
Head pain (no vs yes)	0.10	(0.01, 0.19) ^a	0.10	(0.003, 0.20) ^a	0.10	(-0.02, 0.22)
PTA duration (days [log])	-0.08	(-0.12, -0.05) ^a	-0.07	(-0.11, -0.03) ^a	-0.11	(-0.16, -0.06) ^a

	BTACT composite score (N = 987)		BTACT executive functioning (N = 996)		BTACT episodic verbal memory (N = 1027)	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Age (10 years)	0.02	(-0.02, 0.05)	0.01	(-0.02, 0.05)	0.03	(-0.02, 0.07)
Highest level of education						
Bachelor or greater vs some college	-0.09	(-0.21, 0.03)	-0.17	(-0.30, -0.03)	0.09	(-0.07, 0.25)
Bachelor or greater vs high school diploma	0.14	(0.004, 0.27)	0.10	(-0.04, 0.24)	0.19	(0.02, 0.36)
Bachelor or greater vs less than high school	0.45	(0.31, 0.60) ^b	0.48	(0.32, 0.64) ^b	0.38	(0.19, 0.57) ^b
Some college vs high school diploma	0.23	(0.12, 0.33) ^b	0.27	(0.15, 0.39) ^b	0.10	(-0.04, 0.24)
Some college vs less than high school	0.54	(0.42, 0.67) ^b	0.65	(0.52, 0.78) ^b	0.29	(0.13, 0.45) ^b
High school diploma vs less than high school	0.32	(0.19, 0.45) ^b	0.38	(0.24, 0.52) ^b	0.19	(0.02, 0.36)
Insurance provider						
Private vs medicare	0.31	(0.21, 0.42) ^b	0.31	(0.19, 0.43) ^b	0.31	(0.17, 0.45) ^b
Private vs medicaid	0.28	(0.17, 0.40) ^b	0.27	(0.14, 0.40) ^b	0.33	(0.18, 0.48) ^b
Private vs VA	0.04	(-0.22, 0.30)	0.07	(-0.21, 0.35)	-0.05	(-0.38, 0.29)
Medicare vs medicaid	-0.03	(-0.15, 0.09)	-0.04	(-0.17, 0.10)	0.02	(-0.14, 0.18)
Medicare vs VA	-0.27	(-0.53, -0.01)	-0.24	(-0.52, 0.04)	-0.36	(-0.69, -0.02)
Medicaid vs VA	-0.24	(-0.51, 0.02)	-0.20	(-0.49, 0.09)	-0.37	(-0.72, -0.03)
Opioid use (no vs yes)	-0.09	(-0.18, -0.01) ^a	-0.07	(-0.16, 0.02)	-0.14	(-0.25, -0.03) ^a
GAD-7 total score	-0.01	(-0.02, -0.001) ^a	-0.01	(-0.02, 0.002)	-0.02	(-0.03, -0.004) ^a
PSQI total score	-0.01	(-0.02, -0.001) ^a	-0.02	(-0.03, -0.01) ^a	-0.002	(-0.02, 0.01)
HIT-6		(N = 421)		(N = 424)		(N = 436)
HIT-6	-0.01	(-0.02, -0.004) ^a	-0.02	(-0.03, -0.01) ^a	-0.01	(-0.02, 0.01)
Migraine (features vs non-features)	-0.01	(-0.19, 0.17)	0.01	(-0.19, 0.21)	-0.02	(-0.25, 0.21)
PTA duration (days [log])	-0.06	(-0.12, -0.001) ^a	-0.04	(-0.11, 0.03)	-0.08	(-0.16, -0.01) ^a
Age	-0.03	(-0.08, 0.03)	-0.04	(-0.10, 0.02)	-0.01	(-0.08, 0.05)
Highest level of education						
Bachelor or Greater vs Some College	-0.33	(-0.54, -0.12) ^b	-0.40	(-0.63, -0.17) ^b	-0.09	(-0.36, 0.18)
Bachelor or greater vs high school diploma	-0.09	(-0.32, 0.13)	-0.12	(-0.37, 0.12)	-0.02	(-0.30, 0.27)
Bachelor or greater vs less than high school	0.16	(-0.09, 0.40)	0.19	(-0.08, 0.45)	0.14	(-0.17, 0.45)
Some college vs high school diploma	0.23	(0.07, 0.40) ^b	0.28	(0.10, 0.46) ^b	0.08	(-0.13, 0.28)

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	BTACT composite score (N = 987)		BTACT executive functioning (N = 996)		BTACT episodic verbal memory (N = 1027)	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Some college vs less than high school	0.48	(0.31, 0.66) ^b	0.59	(0.39, 0.78) ^b	0.23	(0.01, 0.46)
High school diploma vs less than high school	0.25	(0.07, 0.43) ^b	0.31	(0.11, 0.51) ^b	0.15	(-0.08, 0.39)
Insurance provider						
Private vs medicare	0.39	(0.22, 0.56) ^b	0.38	(0.19, 0.56) ^b	0.40	(0.19, 0.61) ^b
Private vs medicaid	0.34	(0.17, 0.51) ^b	0.32	(0.14, 0.51) ^b	0.35	(0.14, 0.57) ^b
Private vs va	0.10	(-0.27, 0.47)	0.06	(-0.33, 0.45)	0.06	(-0.42, 0.53)
Medicare vs medicaid	-0.06	(-0.27, 0.47)	-0.06	(-0.25, 0.13)	-0.05	(-0.27, 0.17)
Medicare vs va	-0.30	(-0.66, 0.07)	-0.32	(-0.71, 0.07)	-0.34	(-0.81, 0.13)
Medicaid vs va	-0.24	(-0.61, 0.13)	-0.27	(-0.66, 0.13)	-0.29	(-0.77, 0.19)
Opioid use (no vs yes)	-0.12	(-0.25, 0.01)	-0.06	(-0.21, 0.08)	-0.22	(-0.38, -0.05) ^a
GAD-7 total score	-0.01	(-0.02, 0.01)	-0.01	(-0.02, 0.01)	-0.01	(-0.03, 0.01)
PSQI total score	-0.01	(-0.02, 0.01)	-0.01	(-0.03, 0.01)	-0.004	(-0.02, 0.02)

Abbreviations: BPI: Brief Pain Inventory; BTACT: Brief Test of Adult Cognition by Telephone; CI, confidence interval; GAD-7: General Anxiety Disorder-7; HIT: Headache Impact Test; PSQI: Pittsburgh Sleep Quality Index; PTA, post-traumatic amnesia; VA, Veterans Affairs.

^aSignificant results ($\alpha = 0.05$).

^bBonferroni correction ($\alpha = 0.05/4 = 0.0125$).