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Satisfaction with Life after Mild Traumatic Brain Injury: A TRACK-TBI Study

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Abstract

Identifying the principal determinants of life satisfaction following mild TBI (mTBI) may inform efforts to improve subjective well-being in this population. We examined life satisfaction among participants in the Transforming Research and Clinical Knowledge in Traumatic Brain Injury (TRACK-TBI) study who presented with mTBI (Glasgow Coma Scale [GCS] score = 13–15; $n = 1152$). An L1-regularization path algorithm was used to select optimal sets of baseline and concurrent symptom measures for prediction of scores on the Satisfaction with Life Scale (SWLS) at 2 weeks and 3, 6, and 12 months post-injury. Multi-variable linear regression models (all $n = 744$–894) were then fit to evaluate associations between the empirically selected predictors and SWLS scores at each follow-up visit. Results indicated that emotional post-TBI symptoms (all b = −1.27 to −0.77, all $p < 0.05$), anhedonia (all b = −1.59 to −1.08, all $p < 0.01$), and pain interference (all b = −1.38 to −0.89, all $p < 0.001$) contributed to the prediction of lower SWLS scores at all follow-ups. Insomnia predicted lower SWLS scores at 2 weeks, 3 months, and 6 months (all b = −1.11 to −0.83, all ps < 0.01); and negative affect predicted lower SWLS scores at 2 weeks, 3 months, and 12 months (all b = −1.38 to −0.80, all $p < 0.005$). Other post-TBI symptom domains and baseline socio-demographic, injury-related, and clinical characteristics did not emerge as robust predictors of SWLS scores during the year after mTBI. Efforts to improve satisfaction with life following mTBI may benefit from a focus on the detection and treatment of affective symptoms, pain, and insomnia. The results reinforce the need for tailoring of evidence-based treatments for these conditions to maximize efficacy in patients with mTBI.

Keywords: concussion; life satisfaction; post-concussive symptoms; traumatic brain injury; well-being

Introduction

Traumatic brain injury (TBI) is a major public health problem in the United States and worldwide.[1,2] Understanding the impact of TBI on an individual's overall well-being complements efforts to capture and characterize specific neurocognitive deficits and symptoms that may follow brain injury.[3] One key dimension of well-being is satisfaction with life, which has been defined as an individual's affective and cognitive appraisals of his or her situation relative to his or her expectations.[4] Satisfaction with life is associated with health-related quality of life in patients with a variety of medical conditions,[5] and correlates positively with physical and mental health, social participation, and independence among patients with TBI.[3,6]

Many investigations of satisfaction with life have focused on patients with moderate-to-severe TBI,[3,6–10] who are more likely to

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report significant dissatisfaction than individuals with less severe head injuries.[11,12] Given the substantial differences in functional outcomes, findings regarding satisfaction with life following moderate-to-severe TBI may not generalize to individuals with so-called mild TBI (mTBI; defined here as Glasgow Coma Scale [GCS] score = 13–15), who comprise the large majority of TBI cases.[1,13] Thus, it is important to investigate satisfaction with life specifically within the mTBI population.

Available data suggest that significant dissatisfaction with life may be more prevalent among individuals with a history of mTBI than in the general population.[11] A prospective study of 375 Emergency Department (ED) patients with mTBI[14] found that roughly 45% reported dissatisfaction with life at 6 months post-injury, defined as a score <20 on the Satisfaction with Life Scale (SWLS).[15] Prevalence of dissatisfaction decreased slightly by 12 months post-injury, but 40% remained in the dissatisfied range.[14] It is unclear whether mTBI is associated with lower satisfaction with life than other types of traumatic injury. One prospective study found no significant differences in satisfaction with life among ED patients with mTBI versus orthopedic trauma during the year following injury,[16] but given the relatively small sample ($n = 74$ with mTBI; $n = 40$ with orthopedic injury) this question merits further inquiry.

Investigation is also needed to help determine the primary contributors to life satisfaction after mTBI. If certain socio-demographic, injury-related, or pre-injury clinical characteristics were identified as robust predictors of life satisfaction, this could inform efforts to identify individuals at risk for poorer outcomes (i.e., lower satisfaction), who might benefit from further assessment, monitoring, or intervention. Although some studies have examined isolated socio-demographic or injury characteristics in relation to life satisfaction after mTBI,[14,17–19] few consistent results have emerged, and an analysis that considers a comprehensive array of baseline factors is needed.

In addition to clarifying the role of baseline characteristics, it is crucial to identify modifiable factors associated with life satisfaction following mTBI. It is well known that cognitive, somatic, and affective symptoms may occur after mTBI.[20] Although these often resolve within several weeks of injury, symptom sequelae of mTBI persist and impair functioning for a substantial proportion of patients.[14,21–23] Studies of individuals with mTBI have observed negative associations between satisfaction with life and persistent post-TBI symptoms,[17,21] functional status,[23] pain interference,[19] sleep quality,[19] and mental health problems.[19,21,24,25] More granular analysis of recognized subdomains of post-TBI symptoms (e.g., cognitive symptoms, somatic symptoms) and affective disturbances (e.g., high negative affect, low positive affect)[26] in relation to life satisfaction could yield additional insights. Given the complexity and diversity of clinical presentations following mTBI, clarification of the relative contributions of specific symptom domains to satisfaction with life may help identify treatment targets with greatest potential for improving well-being in this population.

With these considerations in mind, we analyzed data from a large sample of patients enrolled in a multi-site, longitudinal observational study of TBI, to evaluate the contributions of socio-demographic variables, injury characteristics, pre-injury clinical history, and post-TBI symptom domains to satisfaction with life following mTBI. An L1 regularization path algorithm was used to select optimal sets of baseline and concurrent symptom measures for the prediction of life satisfaction at 2 weeks and 3, 6, and 12 months after mTBI. Effects of the empirically selected predictors were then evaluated in multi-variable linear regression models of life satisfaction at each of the four follow-ups. In addition to identifying factors that contributed to the prediction of life satisfaction following mTBI, we estimated the prevalence of significant dissatisfaction with life at each follow-up, and evaluated whether this adverse outcome was more prevalent among patients with mTBI versus orthopedic trauma.

Methods

Participants/Overview

Transforming Research and Clinical Knowledge in Traumatic Brain Injury (TRACK-TBI) is a prospective, multi-center observational study of patients with TBI who presented to EDs at 11 Level 1 trauma centers throughout the United States. Eligibility criteria for TRACK-TBI included presentation to the ED within 24 h of injury, reporting or displaying evidence of alterations of consciousness or amnesia, and having a head trauma warranting clinical evaluation with a non-contrast head computed tomography (CT) scan ordered by the evaluating physician. Exclusion criteria included unlikely to follow-up (e.g., low interest in participation, non-resident, homeless); significant medical history, debilitating mental or neurological disorders, or polytrauma that would interfere with follow-up; language other than English (or Spanish at sites enrolling Spanish speakers); being a prisoner or in custody; pregnancy; being on a mandated psychiatric hold; and current participation in an intervention trial.

The eligible sample for the current study comprised 1152 adult patients who enrolled in TRACK-TBI between February 2014 and May 2016 with GCS score = 13–15 at the time of ED arrival. Some analyses also used data from the TRACK-TBI orthopedic trauma comparison (OTC) group. OTC patients were enrolled with comparable inclusion and exclusion criteria, except that they did not show evidence of TBI (e.g., did not report or display alterations of consciousness or amnesia) and were not required to have had a head CT scan. OTC patients were eligible for inclusion in the current analysis if the window for their 12-month assessment had elapsed by May 2019 ($n = 258$; the included OTC patients were enrolled in TRACK-TBI from January 2016 through April 2018). Due to attrition or missing data on predictor variables, sample sizes for the models of life satisfaction range from 744 to 894 (see table notes for details).

Procedure

All patients or their legal representatives gave written informed consent prior to participation. Baseline assessment was conducted in-person by trained study personnel, as soon as possible after ED evaluation. Information regarding socio-demographic characteristics, pre-injury history, and the presenting injury was collected directly from patients and from medical records. Outcome data were collected in-person at 2 weeks, 6 months, and 12 months post-injury; and by telephone at 3 months post-injury. Other follow-up visits were occasionally conducted via phone if in-person assessment was not possible. Study protocols were approved by the institutional review boards at each participating site.

Measures

Satisfaction with life was measured using the SWLS.[15] The SWLS is a five-item scale that assesses an individual's global satisfaction with his or her life. Respondents rate their level of agreement with statements (e.g., *in most ways my life is close to my ideal*) using a 7-point Likert-style scale (1 = *strongly disagree* to 7 = *strongly agree*). Ratings of each item are summed, yielding total scores ranging from 5 to 35. In the current study, the total SWLS score was prorated if four of the items were completed.

SWLS guidelines suggest that scores <20 reflect varying levels of dissatisfaction with life; scores of 20–24 reflect general satisfaction with life, but with desire for improvement in some areas (mean scores from general population samples in economically developed nations generally fall in this range); and scores $\geq$25 indicate higher levels of satisfaction.[27] The scale and its cutoffs have been validated in samples representative of the general population of the United States and other countries.[27] The total SWLS score was the outcome for the models of satisfaction with life at 2 weeks and 3, 6, and 12 months post-injury. Additionally, a dichotomous variable was derived (SWLS score <20 = 1; SWLS score $\geq$20 = 0) to enable estimation of the prevalence of significant dissatisfaction with life within the mTBI and OTC groups.

The TRACK-TBI baseline and outcome assessments contained an extensive set of measures that could be considered as predictors of satisfaction with life. We considered a broad range of socio-demographic and injury-related variables, as prior studies had not comprehensively evaluated these baseline characteristics in relation to life satisfaction after mTBI. Prior TBI and other (non-TBI) neurological history were considered, to evaluate whether pre-existing neurological vulnerabilities contributed to prediction of life satisfaction after mTBI. Pre-injury psychiatric history was included, given the aforementioned evidence of associations between mental health symptoms and satisfaction with life. With respect to concurrent symptom measures, we aimed to consider a variety of domains while minimizing overlap among the variables.

We prioritized measures of post-TBI symptoms, affective symptoms, insomnia, and pain because these symptoms are commonly reported by patients with mTBI; and prior studies suggest links between these symptom domains and life satisfaction in individuals with mTBI (see Introduction section). Several measures of affective symptoms were available, all of which were highly inter-correlated. Given this, we opted to focus on the broad constructs of negative affect and positive affect. This decision was further based on evidence indicating that positive emotions are more strongly associated with life satisfaction than negative emotions in the general population[26]—a possibility that has not previously been evaluated among individuals with TBI. We also considered affective symptoms as assessed by the Rivermead Post Concussion Symptoms Questionnaire (RPQ),[28] given the prominence of this measure in TBI outcome assessment and because, unlike other available measures, it specifically evaluated affective symptoms that the patient attributed to the TBI. Details follow regarding the measures of the independent variables considered in the analyses.

Socio-demographic characteristics and pre-injury clinical history. Socio-demographic data collected during the baseline interview included self-reported age, sex, race, ethnicity, marital status, years of education, and employment status. Due to low representation of some groups, marital status was coded as Never Married versus Married (includes domestic partner) versus Previously Married (divorced, separated, or widowed); and employment status was coded as Unemployed versus Employed, Student, or Retired. Race was coded as Black versus White or Other; the White and Other groups were collapsed because their SWLS scores were similar at each follow-up, whereas SWLS scores within the Black group were significantly lower.

The baseline TRACK-TBI interview contained three questions about treatment for mental health problems. Patients who reported any history of inpatient treatment, outpatient treatment/counseling, or pharmacotherapy for mental health problems were considered to have a pre-injury psychiatric history. The interview also assessed whether patients had ever had a brain or neurological illnesses before the injury (e.g., epilepsy, tumor, stroke). Patients who responded affirmatively were classified as having a prior neurological disorder. The interview assessed history of prior TBI separately, using a semi-structured assessment[29] that inquired about *injuries to your head or neck that you may have had at any time in your life*. Patients were classified as having prior TBI if they reported $\geq$1 head/neck injury that resulted in alteration/loss of consciousness (LOC) or post-traumatic amnesia (PTA).

Injury characteristics. Medical records and information obtained from patients during the baseline interview were used to categorize injury cause; presence versus absence of major extracranial injury (ECI), LOC, or PTA; and neuroimaging results (positive or negative findings referable to trauma on head CT). Following a previous TRACK-TBI study,[30] specific injury causes were coded as accidental (e.g., road traffic accident, incidental fall) versus violent (e.g., assault). Major ECI was coded as ''present'' if the patient had an Injury Severity Score[31] (ISS) >2 for any non-head/neck region, and ''absent'' if a complete injury record showed ISS for all non-head/neck regions $\leq$2 or if the patient had been discharged from the ED. In all other cases, major ECI was coded ''unknown'' and treated as missing. LOC and PTA were dichotomized as ''yes'' versus ''no,'' with ''suspected'' treated as yes and ''unknown'' treated as missing. CT scans were completed within 24 h of injury and read by a board-certified neuroradiologist; for this study CT results were categorized as ''positive'' versus ''negative'' (i.e., evidence of acute intracranial injury vs. no intracranial injury).

Post-TBI symptoms. The RPQ[28] is a 16-item scale that evaluates symptoms that may occur after TBI. The version of the RPQ used during follow-up visits assessed symptoms that had occurred over the past 7 days. The RPQ instructions direct respondents to rate each symptom on a scale from 0 (*not experienced at all*) to 4 (*severe problem*). Prior to deriving summary scores, item ratings of 1 (*no more of a problem than before*) are recoded as 0, given that they reflect stability of pre-existing symptoms as opposed to onset or worsening of symptoms after TBI.[28] A recent psychometric investigation of the RPQ found strong support for a bifactor model, in which most of the variance in RPQ items was explained by a general factor (supporting a largely unidimensional structure).[32] However, given our interest in the relationships of specific symptom domains to satisfaction with life, we opted to derive RPQ subscales based on a four-factor correlated factor model that also demonstrated good fit for the item-level RPQ data.[32] The four subscales derived for use in the current analysis were: RPQ-somatic (headaches, dizziness, nausea, noise sensitivity, sleep disturbance, fatigue, and restlessness), RPQ-cognitive (forgetfulness, poor concentration, and taking longer to think), RPQ-visual (blurred vision, light sensitivity, and double vision), and RPQ-emotional (feeling irritable, depressed, and frustrated).

Insomnia. The Insomnia Severity Index (ISI)[33] is a seven-item scale that assesses problems related to sleep onset, sleep maintenance, and awakening; dissatisfaction with sleep patterns; interference of sleep problems with daily functioning; and noticeable impairments and level of distress due to sleep dysfunction in the last 2 weeks. The ISI has been validated in samples of individuals with a history of TBI.[34] Ratings of symptom severity/dissatisfaction range from 0 (*not at all*) to 4 (*extremely*). Ratings of all items are summed to create a total ISI score (range 0–28), with higher scores indicating worse insomnia. The total ISI score was prorated if six of the seven items were completed.

Pain. The impact of pain on participants' daily lives was assessed using the Participant Reported Outcome Measurement Information System (PROMIS) Short Form v1.0 Pain Interference 4a scale,[35] which has been validated in various patient populations.[36,37] The scale comprises four items that assess the degree to which pain has interfered with day-to-day activities, work around the home, social activities, and household chores over the past 7 days. Interference in each domain is rated on a 5-point scale with options ranging from *not at all* to *very much*. Item ratings are summed and then converted to T-scores (mean [M] = 50, standard deviation [SD] = 10) that reflect overall pain interference.

Pain severity was also measured at follow-up visits using the PROMIS Short Form v1.0 Pain Intensity 3a scale.[38] Preliminary analyses revealed that Pain Intensity and Pain Interference were highly correlated ($r = 0.84$); thus, we retained just one of these for inclusion in the models of satisfaction with life. Pain Interference was chosen based on its stronger bivariate association with the outcome.

Positive and negative affect.

Low positive affect/anhedonia was measured using three items from the PTSD Checklist-5 (PCL-5), a validated 20-item questionnaire that assesses the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (DSM-5) criteria for post-traumatic stress disorder.[39,40] PCL-5 items measure the severity of symptoms during the past month on a scale ranging from 0 (*not at all*) to 4 (*extremely*). The items selected for measurement of anhedonia were based on factor analytic evidence showing that the items assessing *loss of interest in activities that you used to enjoy*, *feeling distant or cut off from other people*, and *trouble experiencing positive feelings* comprise a distinct factor.[41] Ratings of these items were summed to create an Anhedonia score (range 0–12), with higher scores indicating more severe anhedonia (i.e., lower levels of positive affect).

Factor analyses further indicate that the PCL-5 items that assess *having strong negative beliefs about yourself, other people, or the world*; *blaming yourself or someone else for the stressful experience or what happened after it*; and *having strong negative feelings like fear, horror, anger, guilt, or shame* comprise a distinct factor.[41] Ratings of these three items were summed to create a Negative Affect score (range 0–12), with higher scores indicating greater negative affect. We selected items from the PCL-5 rather than similar items from the Patient Health Questionnaire (PHQ-9)[42] or Brief Symptom Inventory (BSI-18)[43] because of the aforementioned factor analytic evidence supporting derivation of distinct PCL-5 subscales representing low positive affect (anhedonia) and negative affect. Widely accepted factor models of the PHQ-9 and BSI-18 do not support use of subscales corresponding to these domains.[44,45]

Statistical analysis

Propensity score weights were generated using generalized boosted regression models for each visit to account for missing outcomes at follow-up visits. No imputations were made for missing data on predictor variables. Weights-adjusted multivariable linear regression was used to evaluate the associations of baseline and concurrent symptom measures with SWLS scores at 2 weeks and 3, 6, and 12 months post-injury. Prior to fitting the regression models, an L1-regularization path algorithm[46] was used to select an optimal subset of measures for prediction of SWLS score at each follow-up visit, based on the lowest Bayesian information criterion (BIC). The independent variables entered into the algorithm were: age, sex, race, ethnicity, marital status, employment status, years of education, pre-injury psychiatric history, pre-injury neurological history, prior TBI, injury cause, major ECI, LOC, PTA, CT results, RPQ-somatic, RPQ-cognitive, RPQ-visual, RPQ-emotional, insomnia, pain interference, anhedonia, and negative affect. Scores on all concurrent symptom predictors were standardized prior to analysis, so that the regression coefficients would be readily interpretable (i.e., would indicate expected change in SWLS score associated with a 1 SD increase in the symptom score). Final regression models were fit using the empirically selected measures as predictors of SWLS score at each follow-up. All analyses were conducted using the statistical software R (version 3.6.1; http://www.r-project.org).

Results

Sample characteristics at baseline

The majority of the participants with mTBI were male (65.1%) and White (77.1%; with 17.1% Black and 5.8% Other race). Approximately 21.2% identified their ethnicity as Hispanic. At the time of injury, average age was 40.5 years (SD = 17.2) and mean years of education was 13.6 (SD = 2.9). The large majority of participants with mTBI indicated that they were Employed, a Student, or Retired (89.1%). In terms of marital status, 43.3% were Never Married, 36.6% were Married, and 20.2% were Previously Married. A total of 30.4% reported prior TBI, 20.9% had a pre-injury psychiatric history, and 14.2% had a pre-injury (non-TBI) neurological history. The OTC group did not differ significantly from the mTBI group with respect to socio-demographic or pre-injury clinical characteristics.

In terms of injury characteristics, the majority of participants with mTBI had definite or suspected LOC (79.7%) and PTA (70.1%). Approximately one-third (31.2%) had evidence of intracranial injury on CT, and 15.9% had major ECI. The vast majority of mTBIs (94.0%) were attributed to accidental causes, with 6.0% due to violent causes. The OTC group had a significantly lower rate of violent injury cause (0.8%), relative to those with mTBI ($p < 0.001$).

Satisfaction with life at follow-up

Within the mTBI cohort, weighted mean SWLS scores at 2 weeks and 3, 6, and 12 months post-injury were 23.48 (standard error [SE] = 0.25), 24.96 (SE = 0.26), 24.80 (SE = 0.26), and 24.84 (SE = 0.29), respectively. These results indicate that participants with mTBI largely scored in the ''average satisfaction'' range during the year of follow-up, which reflects general satisfaction but with some desire for improvement. The mean SWLS scores of mTBI patients did not differ significantly from the mean SWLS scores of the OTC group (24.42 [SE = 0.51], 25.51 [SE = 0.56], 24.38 [SE = 0.61], and 24.58 [SE = 0.59] at 2 weeks and 3, 6, and 12 months post-injury, respectively; all $p > 0.07$ for all between-group comparisons).

Weighted prevalence of ''significant dissatisfaction with life'' (total SWLS <20) within the mTBI group was 30.6% (SE = 1.5%), 24.1% (SE = 1.5%), 23.2% (SE = 1.5%), and 22.3% (SE = 1.6%) at 2 weeks and 3, 6, and 12 months post-injury, respectively. Corresponding prevalence of this outcome in the OTC group was 20.7% (SE = 2.9%), 20.4% (SE = 3.1%), 25.5% (SE = 3.5%), and 23.1% (SE = 3.6%). The prevalence of dissatisfaction was higher in the mTBI group than in the OTC group at 2 weeks post-injury ($p = 0.003$), but significant differences were not observed at subsequent follow-ups (all $p > 0.13$ for between-group comparisons at 3, 6, and 12 months post-injury).

Models of satisfaction with life following mild TBI

Weights-adjusted multi-variable linear regression models examined predictors of life satisfaction in the mTBI group at each of the four follow-up visits. The measures selected by the algorithm for prediction of SWLS score at 2 weeks are shown in Table 1, along with the results of the multi-variable regression model that estimated associations of the selected measures with SWLS score at 2 weeks. Results of this model showed that insomnia (b = –0.83, $p = 0.008$), pain interference (b = –0.89, $p < 0.001$), emotional symptoms on the RPQ (b = –0.77, $p = 0.012$), anhedonia (b = –1.42,

Table 1. Weights-Adjusted Linear Regression Model of Life Satisfaction 2 Weeks after Mild TBI (N=894)

	b	*95% CI*	χ^2	P
Insomnia (standardized)	**−0.83**	−1.44, −0.22	7.07	0.008
Pain interference (standardized)	**−0.89**	−1.41, −0.37	11.22	0.001
RPQ-emotional (standardized)	**−0.77**	−1.38, −0.17	6.28	0.012
Anhedonia (standardized)	**−1.42**	−2.17, −0.68	14.00	<0.0005
Negative affect (standardized)	**−1.11**	−1.76, −0.45	10.88	0.001

Of 1152 eligible participants, 922 had outcome data (total score on the SWLS) at 2 weeks. Predictor variables for the multi-variable linear regression model of life satisfaction at 2 weeks were selected from a larger pool using the L1-regularization path algorithm; 28 participants with SWLS data at 2 weeks were missing data on one or more predictor variables, resulting in $n=894$ for the final model. The table presents the regression coefficients (all b), their 95% CIs, and the Wald's χ^2 test of the association between each predictor variable and the outcome. The *p*-values correspond to the χ^2 test statistic; statistically significant regression coefficients are denoted in bold type and exact *p*-values for statistically significant coefficients are provided in the Results section.

CI, confidence interval; RPQ, Rivermead Post Concussion Symptoms Questionnaire; SWLS, Satisfaction with Life Scale; TBI, traumatic brain injury.

$p<0.001$), and negative affect (b = −1.11, $p=0.001$) were significantly and independently associated with SWLS score at 2 weeks.

The measures selected by the algorithm for prediction of SWLS score at 3 months are shown in Table 2, along with the results of the corresponding multi-variable regression model. Baseline marital status contributed to prediction of SWLS score at 3 months. Patients who were Never Married (b = −1.58, $p<0.001$) or Previously Married (b = −1.79, $p=0.001$) had lower SWLS scores at 3 months post-injury than those who were Married. Additionally, being Employed (or a Student or Retired) at baseline predicted a higher SWLS score at 3 months post-injury, relative to being Unemployed (b = 2.05, $p=0.002$). Concurrent symptoms that contributed to prediction of (lower) SWLS score at 3 months post-injury were insomnia (b = −1.02, $p<0.001$), pain interference (b = −1.32, $p<0.001$), emotional symptoms on the RPQ (b = −1.11, $p=0.004$), cognitive symptoms on the RPQ (b = −0.65, $p=0.05$), anhedonia (b = −1.59, $p<0.001$), and negative affect (b = −0.80, $p=0.004$).

The measures selected by the algorithm for prediction of SWLS score at 6 months are shown in Table 3, along with the results of the corresponding multi-variable regression model. Baseline marital status contributed to prediction of SWLS score at 6 months. Patients who were Never Married (b = −1.74, $p<0.001$) or Previously Married (b = −1.63, $p=0.007$) had lower SWLS scores at 6 months post-injury than those who were Married. In addition, Black race (relative to White/Other race; b = −1.77, $p=0.007$) and psychiatric history (relative to no psychiatric history; b = −1.53, $p=0.004$) predicted a lower SWLS score at 6 months post-injury. Concurrent symptoms that contributed to prediction of (lower) SWLS score at 6 months post-injury were insomnia (b = −1.11, $p<0.001$), pain interference (b = −1.36, $p<0.001$), emotional symptoms on the RPQ (b = −1.27, $p<0.001$), and anhedonia (b = −1.21, $p=0.001$).

The measures selected by the algorithm for prediction of SWLS score at 12 months are shown in Table 4, along with the results of the corresponding multi-variable regression model. Results of this model showed that pain interference (b = −1.38, $p<0.001$), emotional symptoms on the RPQ (b = −1.13, $p=0.006$), anhedonia (b = −1.08, $p=0.006$), and negative affect (b = −1.38, $p<0.001$) were significantly and independently associated with SWLS score at 12 months.

In summary, pain interference, emotional symptoms on the RPQ, and anhedonia were robust predictors of life satisfaction after mTBI, demonstrating significant and independent associations with SWLS scores at all follow-up assessments. Additionally, insomnia contributed to prediction of life satisfaction at 2 weeks, 3 months, and 6 months; and negative affect contributed to prediction of life satisfaction at 2 weeks, 3 months, and 12 months. The other concurrent symptom measures did not display consistent, independent associations with life satisfaction after mTBI. Most baseline variables under consideration were not selected by the algorithm for prediction of life satisfaction at any of the four follow-up visits. Of the few baseline variables that were selected, marital status was the most consistent contributor to the prediction of life satisfaction, with unmarried individuals displaying significantly lower life satisfaction at 3 and 6 months post-injury.

Table 2. Weights-Adjusted Linear Regression Model of Life Satisfaction 3 Months after Mild TBI (N=814)

	b	*95% CI*	χ^2	P
Never Married (ref: Married)	**−1.58**	−2.43, −0.73		
Previously Married (ref: Married)	**−1.79**	−2.86, −0.71	17.04	<0.0005
Employed/Student/Retired (ref: Unemployed)	**2.05**	0.77, 3.33	9.82	0.002
Insomnia (standardized)	**−1.02**	−1.59, −0.46	12.50	<0.0005
Pain interference (standardized)	**−1.32**	−1.86, −0.78	22.81	<0.0005
RPQ-emotional (standardized)	**−1.11**	−1.86, −0.36	8.41	0.004
RPQ-cognitive (standardized)	**−0.65**	−1.30, −0.002	3.87	0.049
RPQ-somatic (standardized)	0.069	−0.75, 0.89	0.03	0.87
Anhedonia (standardized)	**−1.59**	−2.25, −0.94	22.54	<0.0005
Negative affect (standardized)	**−0.80**	−1.34, −0.25	8.16	0.004

Of 1152 eligible participants, 866 had outcome data (total score on the SWLS) at 3 months. Predictor variables for the multi-variable linear regression model of life satisfaction at 3 months were selected from a larger pool using the L1-regularization path algorithm; 52 participants with SWLS data at 3 months were missing data on one or more predictor variables, resulting in $n=814$ for the final model. The table presents the regression coefficients (all b), their 95% CIs, and the Wald's χ^2 test of the association between each predictor variable and the outcome. The *p*-values correspond to the χ^2 test statistic; statistically significant regression coefficients are denoted in bold type and exact *p*-values for statistically significant coefficients are provided in the Results section.

CI, confidence interval; RPQ, Rivermead Post Concussion Symptoms Questionnaire; SWLS, Satisfaction with Life Scale; TBI, traumatic brain injury.

TABLE 3. WEIGHTS-ADJUSTED LINEAR REGRESSION MODEL OF LIFE SATISFACTION 6 MONTHS AFTER MILD TBI (N=781)

	b	*95% CI*	χ^2	P
Black race (ref: White/Other)	**−1.77**	−3.06, −0.48	7.24	0.007
Never Married (ref: Married)	**−1.74**	−2.62, −0.86		
Previously Married (ref: Married)	**−1.63**	−2.80, −0.46	17.20	<0.0005
Employed/Student/Retired (ref: Unemployed)	1.14	−0.33, 2.61	2.30	0.13
Any psychiatric history (ref: None)	**−1.53**	−2.57, −0.49	8.34	0.004
Insomnia (standardized)	**−1.11**	−1.75, −0.48	11.80	0.001
Pain interference (standardized)	**−1.36**	−1.97, −0.75	19.17	<0.0005
RPQ-emotional (standardized)	**−1.27**	−1.92, −0.63	15.04	<0.0005
Anhedonia (standardized)	**−1.21**	−1.96, −0.47	10.19	0.001
Negative affect (standardized)	−0.55	−1.13, 0.04	3.39	0.066

Of 1152 eligible participants, 822 had outcome data (total score on the SWLS) at 6 months. Predictor variables for the multi-variable linear regression model of life satisfaction at 6 months were selected from a larger pool using the L1-regularization path algorithm; 41 participants with SWLS data at 6 months were missing data on one or more predictor variables, resulting in $n=781$ for the final model. The table presents the regression coefficients (all b), their 95% CIs, and the Wald's χ^2 test of the association between each predictor variable and the outcome. The *p*-values correspond to the χ^2 test statistic; statistically significant regression coefficients are denoted in bold type and exact *p*-values for statistically significant coefficients are provided in the Results section.

CI, confidence interval; RPQ, Rivermead Post Concussion Symptoms Questionnaire; SWLS, Satisfaction with Life Scale; TBI, traumatic brain injury.

Discussion

In this study of adults presenting to Level 1 trauma centers with mTBI, affective symptoms, pain interference, and insomnia emerged as the most robust predictors of satisfaction with life during the year following injury. Feelings of depression, irritability, and frustration that had emerged or worsened since the index TBI (as reported on the RPQ) were associated with lower satisfaction with life at all follow-ups, whereas other post-TBI symptom domains (visual, somatic, and cognitive symptoms on the RPQ) lacked consistent, independent associations with life satisfaction. Results further indicated that the affective symptoms related to life satisfaction after mTBI included both high negative affect and low positive affect (i.e., anhedonia). The finding that the anhedonia measure contributed to prediction of life satisfaction at all four outcome assessments is consistent with evidence from the general population that the experience of positive emotions is closely linked to life satisfaction.[26]

TABLE 4. WEIGHTS-ADJUSTED LINEAR REGRESSION MODEL OF LIFE SATISFACTION 12 MONTHS AFTER MILD TBI (N=744)

	b	*95% CI*	χ^2	P
Insomnia (standardized)	−0.57	−1.19, 0.05	3.22	0.073
Pain interference (standardized)	**−1.38**	−2.01, −0.76	18.95	<0.0005
RPQ-emotional (standardized)	**−1.13**	−1.92, −0.33	7.72	0.005
RPQ-cognitive (standardized)	−0.42	−1.15, 0.30	1.32	0.25
Anhedonia (standardized)	**−1.08**	−1.85, −0.31	7.55	0.006
Negative affect (standardized)	**−1.38**	−2.02, −0.75	18.25	<0.0005

Of 1152 eligible participants, 758 had outcome data (total score on the SWLS) at 12 months. Predictor variables for the multi-variable linear regression model of life satisfaction at 12 months were selected from a larger pool using the L1-regularization path algorithm; 14 participants with SWLS data at 12 months were missing data on one or more predictor variables, resulting in $n=744$ for the final model. The table presents the regression coefficients (all b), their 95% CIs, and the Wald's χ^2 test of the association between each predictor variable and the outcome. The *p*-values correspond to the χ^2 test statistic; statistically significant regression coefficients are denoted in bold type and exact *p*-values for statistically significant coefficients are provided in the Results section.

CI, confidence interval; RPQ, Rivermead Post Concussion Symptoms Questionnaire; SWLS, Satisfaction with Life Scale; TBI, traumatic brain injury.

Our findings broadly converge with prior results[19,21,24,25] and strengthen the evidence linking affective symptoms to life satisfaction in adults with recent mTBI by considering these symptoms alongside a wide range of baseline characteristics and other post-TBI symptoms. Given the evidence of a strong relationship between affective symptoms and life satisfaction in this population, it is notable that the level of interference in activities attributed to pain, as well as the severity of sleep problems, also contributed to the prediction of satisfaction with life in multi-variable models (i.e., their effects were significant even after adjusting for affective symptoms). Along with affective symptoms, these domains should be key targets of efforts to improve satisfaction with life in patients with mTBI.

Although our models identified factors contributing to the prediction of life satisfaction in patients with mTBI, the analysis did not evaluate the specificity of these effects to individuals with mTBI. Indeed, evidence suggests that high negative affect, low positive affect, sleep problems, and pain-related variables are associated with life satisfaction in non-TBI samples.[26,47,48] Additionally, our study did not provide evidence that patients' satisfaction with life was related to (or impacted by) their recent mTBI. Data pertaining to pre-injury life satisfaction were not available; thus, the degree to which patients' SWLS scores at follow-up reflected stability versus changes in life satisfaction from pre- to post-injury could not be determined.

On the other hand, the study did provide information regarding absolute levels of satisfaction with life at 2 weeks and 3, 6, and 12 months post-injury. Descriptive analyses showed that the mean SWLS score of the mTBI group was relatively stable and remained in the ''average satisfaction'' range throughout the year of follow-up. The prevalence of ''significant dissatisfaction'' (SWLS <20) was higher at 2 weeks post-injury than at later follow-ups (30.6% vs. 22.3–24.1%). This pattern may suggest that, for some patients, mTBI has a short-term adverse impact on overall life satisfaction but that their level of satisfaction rebounds by 3 months post-injury. However, this interpretation is tentative given the lack of information regarding pre-injury life satisfaction. Converging with prior results,[16] the mean SWLS scores of patients with mTBI versus orthopedic trauma did not differ significantly at any point during the year of follow-up. Additionally, although the prevalence of ''significant dissatisfaction'' was higher in the mTBI group versus the OTC group at 2 weeks post-injury, rates of this adverse outcome were comparable in the two groups at all subsequent follow-up visits. In general, prevalence of dissatisfaction was lower in this TRACK-TBI mTBI cohort than among patients with mTBI who participated in the TRACK-TBI pilot study.[14] Reasons for this are not entirely clear, but the discrepancy may be due to differences in sample characteristics or methodology (e.g., application of propensity weights in the current analysis to mitigate impacts of attrition).

As previously noted, the predictive analysis also considered baseline socio-demographic, injury-related (e.g., cause of injury, CT results), and clinical history variables (e.g., prior TBI). Marital status was the only variable that contributed to prediction of life satisfaction at multiple follow-ups. At 3 and 6 months post-injury, married individuals reported higher satisfaction with life than those who were never married or divorced/separated/widowed. Although prior studies have not necessarily found marital status to relate to satisfaction with life after mTBI,[24] social support is an established correlate of subjective well-being among individuals with mTBI[19,21]; the positive relationship between marriage and life satisfaction following mTBI may reflect benefits of social support available in the context of the marital relationship.

The relationships of affective symptoms, pain interference, and insomnia with life satisfaction provide a further rationale for periodic monitoring of these symptom domains following mTBI. Evidence-based treatments are available for these conditions, and efforts to refine interventions to maximize efficacy in TBI-exposed individuals are ongoing.[49] Although our analysis does not demonstrate a causal relationship between affective symptoms, pain interference, or insomnia and life satisfaction, it is plausible that amelioration of such symptoms would result in substantial increases in patients' life satisfaction. Future studies should evaluate the extent to which interventions targeting affective disturbances, pain, and insomnia improve the life satisfaction of individuals with mTBI. Alternate approaches such as Mendelian randomization analyses[50] could also be used to examine hypotheses regarding causal relationships between these symptom domains and life satisfaction.

Results of this study must be interpreted in light of several limitations. Most study measures relied on patient self-report and are vulnerable to response biases. In particular, responses to self-report questionnaires may be influenced by current affective state; for example, a high level of negative affect could bias a respondent toward a more negative view of his or her life at that moment. Such bias could contribute to the associations observed between affective variables and life satisfaction. An additional issue is that the measures of anhedonia and negative affect came from the PCL-5, and instructions for that scale direct respondents to think about symptoms that may have occurred in response to a stressful experience. The PCL-5 subscales may not have captured anhedonia and negative affect that participants viewed as being unrelated to stressful life events. Finally, although the SWLS is a core measure of the common data elements for TBI outcome assessment,[51] it is a generic as opposed to a population-specific measure, and may not be sensitive to subtler decrements in well-being after mTBI.[52] Future studies should examine subjective well-being after mTBI using instruments that assess life satisfaction in a more detailed manner, and with specific focus on areas of life that may be more impacted by brain injury (e.g., Quality of Life after Traumatic Brain Injury[QOLIBRI][53]).

It is also important to note that the current analysis was based on data from ED patients who had an arrival GCS score = 13–15 and were referred for a head CT, most of whom had definite or suspected LOC or PTA. Results may not generalize to patients who present to the ED with head injuries that did not result in LOC or PTA (i.e., mTBI with alteration of consciousness only). Results also may not generalize to patients who present to the ED but whose initial triage does not prompt referral for head CT or to individuals with mTBI who do not seek treatment in the ED.

In conclusion, we found that affective symptoms, pain interference, and insomnia were consistently associated with lower life satisfaction during the year following mTBI, whereas other post-TBI symptom domains and baseline characteristics did not contribute substantially to prediction of life satisfaction. Efforts to improve life satisfaction in the mTBI population may benefit from a focus on monitoring and treatment of affective symptoms, pain, and insomnia. The results of this study further emphasize the need for refinement of evidence-based treatments for mental health problems, pain, and insomnia to maximize efficacy of these interventions among individuals with recent mTBI.

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