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Injury Severity and Depressive Symptoms in a Post-acute Brain Injury Rehabilitation Sample

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Abstract

This study explored the relationship between injury severity and depressive symptoms for treatment-seeking individuals with traumatic brain injury (TBI). The Mayo Classification System was used to classify TBI severity in 72 participants who completed the Patient Health Questionnaire at admission and at dismissal from rehabilitation. Patients with mild TBI reported more depressive symptoms than those with moderate or severe TBI at admission and at dismissal. Although injury severity groups differed by gender composition, gender had no effect on severity of depressive symptoms. All participants reported fewer depressive symptoms at dismissal from rehabilitation, including lower endorsement of dysphoria by discharge. Participants with mild TBI, however, continued to report depressive symptoms of a mild severity at dismissal, with residual problems with anhedonia. These findings underscore the benefit of interdisciplinary post-acute rehabilitation services for persons with TBI of any severity, including those with mild injury.

Keywords Depression · Injury severity · Mild brain injury · Rehabilitation · Traumatic brain injury

Abbreviations

CBT	Cognitive behavioral therapy
MCS	Mayo Classification System
PHQ-9	Patient Health Questionnaire
PTSD	Posttraumatic stress disorder
TBI	Traumatic brain injury

Depression is prevalent in the first year after a traumatic brain injury (TBI) (Alway, Gould, Johnston, McKenzie, & Ponsford, 2016; Bombardier et al., 2010; Bombardier, Hoekstra, Dikmen, & Fann, 2016). Roughly a third of patients develop clinically significant depression during the first year following TBI (Bombardier et al., 2016; Hart et al., 2012; Rapoport et al., 2003a, 2003b), and many of those who develop depression experience persistent symptoms (Hart et al., 2012). Risk factors for posttraumatic depression include personal psychiatric history, family psychiatric history, alcohol or other substance abuse, and adverse life events or psychosocial stressors (Alway et al., 2016; Bombardier et al., 2016; Gomez-Hernandez, Max, Kosier, Paradiso, & Robinson, 1997; Iverson, 2005; Jorge et al., 1993; Jorge & Starkstein, 2005; Lange et al., 2013; Losoi et al., 2016). There are mixed findings with respect to how gender is associated with risk of depression following TBI, with some studies suggesting that females have a greater postinjury risk, and others arguing for no gender differences (Covassin & Bay, 2012; Hart et al., 2011; Liossi & Wood, 2009; Preiss-Farzanegan, Chapman, Wong, Wu, & Bazarian, 2009). Veterans with mild TBI returning from active duty have more mental health care needs and use outpatient health care services at twice the rate compared with veterans without TBI (Taylor et al., 2017). Effective treatment of depressive symptoms for patients with TBI is necessary to improve quality of life, maximize psychosocial outcomes, and decrease costly health care utilization.

Because treatment of mild TBI, as opposed to moderate to severe TBI, typically occurs in clinical silos, it is

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difficult to examine differences in outcomes like depression across the full spectrum of TBI. Interdisciplinary post-acute TBI rehabilitation programs have been developed to help patients with moderate to severe TBI with vocational and psychosocial reintegration following acute treatment (Malec & Basford, 1996; Malec, Smigielski, DePompolo, & Thompson, 1993). Patients with mild TBI are more likely to receive treatment in outpatient primary care or specialty care clinics, such as sports medicine centers (McCrea et al., 2009). Wardlaw, Hicks, Sherer, and Ponsford (2018) astutely highlighted this schism in treatment of brain injury patients in a study of resiliency in patients with all-severity TBI. Developing interdisciplinary treatment programs that actively recruit and that are equipped to treat patients with all-severity TBI would not only be a welcome resource for patients but also benefit primary care providers, health care institutions, communities, and scientific research.

Prospective research for all-severity TBI patients (i.e., prospective cohort studies) generally reveals that depression has no correlation with brain injury severity. In the first cohort study of patients with all-severity TBI, Rapoport, McCauley, Levin, Song, and Feinstein (2002) found no association between injury severity and depressive symptoms at 3 months postinjury. Likewise, in an all-severity TBI cohort sample drawn from hospitalized inpatients in a level 1 trauma center, Malec, Testa, Rush, Brown, and Moessner (2007) found no relationship between injury severity and depression at 1 month postinjury (early depression) or at 1 year postinjury (late-onset depression). However, patient beliefs related to the degree of injury-related impairment were associated with depressive symptoms, highlighting a potential cognitive behavioral etiology of mood symptoms. Malec, Brown, Moessner, Stump, and Monahan (2010) replicated their findings and again found no relationship between injury severity and depression in patients with post-acute TBI. Further, Bombardier et al. (2010) indicated that while over half of their sample met criteria for major depression by one year, brain injury severity was not useful in predicting who developed depression.

Some prospective cohort studies investigating the association between injury severity and mood have compared subgroups within the spectrum of TBI injury severity. For example, those studies compared how injury severity may correlate with mood in patients with mild or complicated mild TBI, or in patients with complicated mild or severe TBI, and have yielded mixed results (Dikmen, Bombardier, Machamer, Fann, & Temkin, 2004; Singh, Mason, Lecky, & Dawson, 2018). *Complicated mild TBI* refers to instances when a person meets the general criteria for mild TBI, but the injury or recovery may be complicated by a small hemorrhage or skull fracture (Iverson, 2006). Dikmen et al. (2004) indicated that a longer time to follow commands was associated with less severe depression at 1 month postinjury between persons with complicated mild/moderate or severe TBI; persons with less severe TBI reported more symptoms of depression than those with more severe TBI. At 1 year, however, injury severity had no relationship with severity of depressive symptoms (Dikmen et al., 2004). It is believed that poor insight and awareness of deficits in the acute phase of recovery following TBI may protect those with more severe injury from depressive symptoms (Evans, Sherer, Nick, Nakase-Richardson, & Yablon, 2005; Fleming, Strong, & Ashton, 1998). As insight into deficits associated with severe TBI improves with time, depressive symptoms may increase and match those of patients with less severe injury.

Treatment seekers are a unique subset of the brain injury population. Less is known about the relationship between injury severity and depression in these post-acute treatment-seeking brain injury patients. We cannot assume that findings from prospective cohort studies generalize perfectly to clinical samples as treatment seekers are often motivated to relieve suffering related to physical, vocational, emotional, or other psychosocial dysfunction.

It is not uncommon to see an inverse association between injury severity and symptoms following TBI, including mood symptoms, in treatment-seeking samples. Alexander (1992) studied an all-severity post-acute TBI treatment-seeking sample and found that those with mild TBI had higher symptoms of depression, more severe headaches, and increased dizziness, compared with patients with moderate–severe TBI. Other investigators documented an inverse relationship between injury severity and pain, such as headache or diffuse pain (Hoem Nordhaug et al., 2016; Lucas, Hoffman, Bell, & Dikmen, 2014; Nampiaparampil, 2008; Solomon, 2009).

The influence of injury severity on intensity of postconcussive symptom reporting may be mediated by emotional distress (Belanger, Vanderploeg, & Kretzmer, 2009; Hoge et al., 2008). Hoge et al. (2008) surveyed a large sample of veterans returning from Iraq and found a significant positive relationship between injury severity and postconcussive symptoms and daily functioning (e.g., health concerns and somatic complaints, lower work functioning), but depression and posttraumatic stress disorder (PTSD) appeared to mediate these associations. While Belanger, Kretzmer, Vanderploeg, and French (2010) also highlighted an inverse association between injury severity and postconcussive symptoms, PTSD was again shown to mediate the relationship. Those data emphasize the importance of assessing and treating emotional well-being of patients after brain injury.

Although cohort samples of all-severity TBI have generally shown no relationship between brain injury severity and mood during post-acute recovery (Malec et al., 2007; Rapoport et al., 2002), studies exploring the relationship between treatment-seeking samples have suggested a

possible inverse association between injury severity and postconcussive symptoms, including depression (Alexander, 1992; Farrell-Carnahan et al., 2015; Hoem Nordhaug et al., 2016; Hoge et al., 2008; Lucas et al., 2014; Nampiaparampil, 2008; Solomon, 2009). Therefore, this investigation sought to determine whether brain injury severity correlated with depressive symptoms in post-acute TBI treatment seekers. Depression is important to target in treatment as it has also been shown to mediate the relationship between brain injury severity and magnitude of postconcussive symptomatology in some samples (Belanger et al., 2009).

This study also investigated whether patients, regardless of brain injury severity, report fewer depressive symptoms following interdisciplinary treatment. The effectiveness of these programs is well documented for vocational and psychosocial outcomes following moderate to severe brain injury (Cicerone et al., 2005; Malec & Basford, 1996). However, more research is needed to explore the mental health benefits of interdisciplinary rehabilitative programs for patients with more severe injury (Glintborg & Hansen, 2016). Additionally, there is a call to better document the benefits of interdisciplinary treatment of patients with mild brain injury in post-acute recovery, particularly in a civilian setting (Batten & Pollack, 2008; Management of Concussion/mTBI Working Group, 2009). Interdisciplinary rehabilitation programs have been established for veterans with mild brain injury and frequent PTSD episodes after returning from combat. These programs have shown promise for reducing symptoms of postconcussive syndrome, depression, and posttraumatic anxiety (Batten & Pollack, 2008; Janak et al., 2017; Speicher, Walter, & Chard, 2014).

To meet the primary study objectives, the following hypotheses were offered:

(1) Treatment-seeking patients with mild TBI report higher depressive symptoms at admission and at discharge from rehabilitation than patients with moderate to severe TBI.
(2) Treatment-seeking patients with mild or moderate to severe TBI report a significant reduction in depressive symptoms between admission and dismissal from rehabilitation.
(3) Treatment-seeking patients, regardless of brain injury severity (i.e., all-severity TBI), report a significant decrease in endorsement rates of anhedonia and dysphoria between admission and dismissal from rehabilitation.
(4) Anhedonia and dysphoria will also decrease when endorsement rates are inspected within subgroups of TBI severity (e.g., mild, moderate, or severe TBI) between admission and dismissal from rehabilitation.

Methods

Participants

The participants were 72 adults (age ≥18 years) with TBI and without comorbid central nervous system diagnoses who were referred by physicians from 2011 to 2015 for individualized post-acute TBI multidisciplinary rehabilitation at a Midwestern tertiary medical center. Eligible participants were referred for rehabilitation and not for litigious reasons, neuropsychological evaluation, workman's compensation, or disability determinations. Although some patients may have received neuropsychological evaluations during their treatment to assist with care management, the evaluations were not a standard part of care, particularly for patients with mild TBI. Brief intake assessments were completed for all participants.

Measures

Mayo Classification System for TBI Severity

To address the difficulties in classifying the severity of TBI in research and rehabilitation settings, Malec et al. (2007) created the Mayo Classification System (MCS). The MCS uses all available acute injury data in the medical records, including trauma-related neuroimaging abnormalities, rather than reflecting single classifiers in isolation, Glasgow Coma Scale score, duration of post-traumatic amnesia, loss of consciousness, and specified postconcussive symptoms to classify TBI. The MCS has been more accurate for classifying TBI than the use of single indicators alone (Malec et al., 2007). Therefore, in rehabilitation settings, the MCS has excellent utility as a correlate for outcomes such as mood. Brain injury classifications used in the present study were (1) *definite* (i.e., moderate or severe TBI; 60% of our participants) and (2) *mild* (possible TBI [14% of participants] or probable TBI [26%]) (Table 1).

Patient Health Questionnaire

The Patient Health Questionnaire (PHQ-9) (Kroenke, Spitzer, & Williams, 2001) is a nine-item assessment that uses a four-choice Likert scale, which allows participants to rate how frequently they experience depressive symptoms, from 0 (not at all) to 3 (nearly every day). PHQ-9 scores correspond with severity of depression as follows: 5 (mild), 10 (moderate), 15 (moderately severe), and 20 (severe). The PHQ-9 is a valid and reliable measure of

Table 1 Mayo classification system for traumatic brain injury (TBI) severity

Severity of TBI	Classification criteria
Moderate or severe (definite)	At least one of the following: Death due to TBI LOC ≥ 30 min PTA ≥ 24 h Worst GCS score in the first 24 h is < 13
	At least one of the following: Intracerebral, subdural, or epidural hematoma Cerebral or hemorrhagic contusion Penetrating TBI Subarachnoid hemorrhage Brainstem injury
Mild (probable)	Not definite TBI, and at least one of the following: LOC momentary or < 30 min PTA momentary or < 24 h Skull fracture with dura intact
Symptomatic (possible)	Not definite TBI or probable TBI and at least one of the following: Blurred vision Confusion Dazed Dizziness Focal neurologic symptoms Headache Nausea

GCS Glasgow Coma Scale, *LOC* loss of consciousness, *PTA* posttraumatic amnesia

Reproduced with permission from Malec et al. (2007)

depression severity and is useful for patients with TBI (Donders & Pendery, 2017; Fann et al., 2005).

We used items 1 and 2 on the PHQ-9 to evaluate if patients reported emotionally laden symptoms of depression. The PHQ-9 assesses not only emotional symptoms but also physical, vegetative, and cognitive symptoms, all of which are frequently reported after TBI (Farrell-Carnahan et al., 2015; Nampiaparampil, 2008). Item 1 assesses anhedonia, and item 2 assesses dysphoria. At admission and at dismissal, participants who chose a rating of 1, 2, or 3 were classified as endorsing anhedonia (item 1) or dysphoria (item 2). Participants who chose zero were classified as not endorsing those symptoms. This investigation compared rates of endorsement of these emotional symptoms at admission and at dismissal for the overall group and for the mild and definite TBI groups.

Procedure

Participants were referred for treatment to the Mayo Clinic Outpatient Brain Rehabilitation Program, which offers an outpatient community reentry program (Malec & Basford, 1996) with rehabilitation treatment focused on patient need and vocational and independent living social reintegration outcomes. In this program, patients with TBI work with a team that is led by a physiatrist or a clinical nurse specialist and may include a neuropsychologist, clinical social worker, speech therapist, occupational therapist, vocational rehabilitation counselor, and physical therapist, according to the patient's clinical needs. In addition, patients are referred to other specialties as needed, and patients receive psychotherapy (i.e., cognitive behavioral therapy [CBT]) and cognitive rehabilitation as part of their treatment.

Demographic information and severity of TBI, according to the MCS, were collected for each participant upon admission. During a 30-min admission session, the PHQ-9 was administered along with other measures by a qualified rehabilitation professional. All measures were reviewed with the patient before completion to facilitate understanding. Discharge questionnaires, which include the PHQ-9, were typically completed by patients on-site after their last scheduled appointment.

Analysis

Demographic and clinical characteristics for the two TBI classification groups (mild and definite) were summarized as mean (SD). Associations of categorical variables (gender, marital status, race, and education) and TBI groups were compared with χ^2 tests. One-way analysis of variance was used to compare the groups for number of days since the injury. Because some models using PHQ-9 scores had missing data, we performed additional group comparisons (χ^2 and t tests) to show that those patients included in the

PHQ-9 models vs. missing from analyses were demographically similar. After analyzing the characteristics of the injury severity groups, gender and days since injury were identified as potential confounders between injury severity and depressive symptoms at admission and/or dismissal from rehabilitation. An analysis of covariance with gender and days since injury as covariates was performed to compare injury severity groups according to depressive symptoms. Paired *t* tests were used to test for change on the PHQ-9 between admission and dismissal for the overall sample and for the two TBI groups. McNemar tests were used to investigate whether the rate of endorsing anhedonia or dysphoria was significantly different between admission and dismissal ($p < .05$ was considered significant) in the overall sample, in persons with mild TBI, and in persons with mild-to-moderate TBI. The McNemar test is useful for testing change in response rate across different time points for the same participants. Statistical analyses were conducted with SAS version 9.4 (SAS Institute Inc, Cary, North Carolina).

Results

Demographics

Demographic data for the 72 participants are presented in Table 2. The average time between injury and admission for rehabilitation was 441 days. Half the participants were married, and most were white, middle aged, and well educated. In the mild TBI group, more patients were women (69%); in the definite TBI group, more patients were men (63%).

Participants with probable TBI and possible TBI were combined into the mild TBI group to balance the definite TBI group by sample size. Although patients with possible or probable TBI differed slightly in the number of days since the injury before they were admitted to rehabilitation, we combined these groups into the mild TBI group because criteria for both possible TBI and probable TBI meet generally accepted criteria (i.e., equivalent) for diagnosing mild TBI (Malec et al., 2007). Moreover, patients in the possible and probable TBI groups did not differ on any important variables under investigation (e.g., gender, education, or PHQ-9 results). Although days since injury varied slightly between the possible and probable TBI groups, days since injury did not correlate significantly with PHQ-9 scores for the mild TBI group (Spearman $\rho = -0.009$, $p = .96$).

A portion of subjects who completed the PHQ-9 at admission did not complete the PHQ-9 at dismissal (16 of 56; 29%). Therefore, results for dismissal and change from admission may potentially be confounded by characteristics related to these missing data. Comparison of the characteristics in Table 2 revealed that patients with no PHQ-9 dismissal scores ($n = 16$) did not significantly differ in age, TBI classification, marital status, race, employment, or gender from patients who completed the PHQ-9 at dismissal ($n = 56$). However, they had a significantly longer time since their injury (mean [SD]: 593 [708] vs. 410 [708]; $p = .03$) when compared with patients who completed the dismissal PHQ-9. Therefore, models of PHQ-9 scores include days from injury as a covariate (see below).

Table 2 Demographic and clinical characteristics of patients

Characteristic	TBI classification of patients[a,b]		*p* value
	Definite ($n = 43$)	Mild ($n = 29$)	
Age (years)	47.1 (20.1)	44.9 (12.5)	.60
Male	27 (62.8)	9 (31.0)	.008
Married	20 (46.5)	16 (55.2)	.47
White	39 (90.7)	27 (93.1)	.72
Education > 12 years	25 (58.1)	18 (62.1)	.88
Time since injury (days)	493.3 (776.3)	388.1 (598.2)	.21

TBI traumatic brain injury

[a]*Definite* includes moderate or severe TBI (60% of total sample); *mild*, probable (26%) or possible (14%) TBI

[b]Continuous data are summarized as mean (SD); categorical data as number of patients (percentage of sample)

Relationship Between Injury Severity and Mood

Because gender and days after injury are potential confounders between injury severity and mood, they are included as covariates in our models exploring the relationship between injury severity and mood at time of admission and dismissal from rehabilitation. As shown in Table 3, injury severity significantly impacts reporting of depressive symptoms (as measured with the PHQ-9) at admission ($F = 8.81$, $p < .01$) and dismissal ($F = 5.9$, $p < .02$) after factoring out gender and days since injury. Neither gender nor days since injury were significant covariates. Treatment-seeking patients with mild TBI reported more depressive symptoms than patients with moderate or severe TBI at admission and dismissal.

Table 3 Effect of injury severity on PHQ-9 scores adjusted for gender and days since injury

Time of PHQ-9	TBI classification of patients[a,b]		*p* value
	Definite ($n = 43$)	Mild ($n = 29$)	
Admission	6.3 (4.9)	10.9 (6.6)	.004
Dismissal	4.0 (5.5)	7.8 (6.1)	.02

PHQ-9 Patient Health Questionnaire, *TBI* traumatic brain injury

[a]*Definite* includes moderate or severe TBI; *mild*, probable or possible TBI

[b]Data are presented as mean (SD)

Treatment Effects on Mood

Results of paired *t* tests showed that depressive symptoms decreased modestly between admission and dismissal for participants in both TBI severity groups. Although depressive symptoms diminished for all patients between admission and dismissal from rehabilitation, regardless of injury, patients with mild TBI still reported depressive symptoms in the mild range of severity (mean PHQ-9 score, 8) when they completed rehabilitation (Table 4).

The rate of endorsing emotionally laden symptoms of depression between admission and dismissal from rehabilitation was examined for only a subset of the overall sample ($n = 45$) because responses to individual items on the PHQ-9 were not recorded in the medical record for all participants. In the all-severity TBI sample, endorsement rates of anhedonia declined significantly between admission and dismissal from rehabilitation (63% vs. 44%, $p = .003$). Likewise, endorsement rates of dysphoria declined significantly between admission and dismissal from rehabilitation in the all-severity sample (64% vs. 38%, $p = .003$). Therefore, rates of emotionally laden symptoms of depression decreased between admission and dismissal for a substantial proportion of our all-severity sample (19% for anhedonia vs. 26% for dysphoria). Also, very few patients (< 1%) who did not endorse these symptoms at admission endorsed anhedonia or dysphoria at completion of the program. This would argue against negative treatment effects.

Rates of endorsing anhedonia or dysphoria were also inspected within subsets of mild ($n = 21$) and definite ($n = 24$) TBI groups. Results indicated that endorsement rates of anhedonia did not change significantly from admission to dismissal for patients with mild TBI (71% vs. 67%, $p = .71$), but rates of endorsing dysphoria decreased significantly (76% vs. 48%, $p = .03$). Patients with definite TBI reported reduced rates of anhedonia (58% vs. 25%, $p = .01$) and dysphoria (54% vs. 29%, $p = .03$). Patients with mild or definite TBI reported less dysphoria over time, while only persons with definite TBI reported less anhedonia.

Discussion

Injury Severity Effect in Treatment Seekers

Although treatment-seeking patients with mild and definite TBI presented for rehabilitation reporting at least mild depressive symptoms, patients with mild TBI reported significantly more depressive symptoms than moderate–severe TBI patients. These findings suggest brain injury severity correlates significantly with depressive symptoms among treatment-seeking patients with TBI in the post-acute phase of recovery. Results are consistent with a trend in the literature that indicates treatment-seeking patients with mild TBI in the post-acute phase of recovery report some symptoms (e.g., depression, headache, or generalized pain) with greater intensity compared to patients with moderate or severe injury (Alexander, 1992; Belanger et al., 2009; Hoem Nordhaug et al., 2016; Nampiaparampil, 2008; Singh et al., 2018). This trend was also recently observed in a prospective cohort study of patients with mild to complicated mild TBI recruited from the emergency department (Singh et al., 2018). Patients with mild TBI reported more depression at 3 months postinjury than those with complicated mild TBI (Singh et al., 2018).

Higher symptom reporting in patient groups with less severe injury seems counterintuitive in health care. With respect to brain injury, this leads some laypersons and health care providers to dismiss or minimize persisting symptoms following mild injury (e.g., postconcussive syndrome). However, there may be meaningful individual differences influencing how symptoms non-specific to an injury or illness (e.g., blood pressure, fever, nausea, depressive symptoms, diffuse pain, or headache) are expressed (Obermeyer, Samra, & Mullainathan, 2017). When different symptom profiles are observed across individuals or subgroups with the same injury, research needs to identify what differences exist in which patients and in what settings. Treatments can then be "individualized" to match the needs of each patient group.

Why might patients with mild brain injury report more symptoms—such as depression—compared with patients with more severe injury? Although the answer to this question remains elusive, most psychological research suggests

Table 4 Change in PHQ-9 score from admission to dismissal

Measure	All patients		TBI classification[a]			
	(*N* = 72)		Definite (*n* = 43)		Mild (*n* = 29)	
	Mean (*SD*)	*p* value	Mean (*SD*)	*p* value	Mean (*SD*)	*p* value
Change in PHQ-9	− 2.7 (5.6)	< .001	− 2.3 (5.6)	.02	− 3.3 (5.6)	.01

PHQ-9 Patient Health Questionnaire, *TBI* traumatic brain injury

[a]*Definite* includes moderate or severe TBI; *mild*, probable or possible TBI

that cognitive behavioral and psychosocial factors (i.e., self-attributions, injury and recovery expectations, personal biases, or disability and litigation factors) can precipitate symptom onset or contribute to symptom perpetuation (Iverson, 2005; Lange et al., 2013; McCrea, 2008). Cognitive behavioral theory suggests that cognitions associated with injury and recovery (i.e., negative/irrational vs. accurate appraisals, distorted/irrational vs. accurate beliefs, and inappropriate/irrational vs. accurate expectations) and postinjury behavior (e.g., disengagement from routine activities, reaction to symptoms) impact postinjury mood and outcomes (Deary, Chalder, & Sharpe, 2007; Mittenberg, Tremont, Zielinski, Fichera, & Rayls, 1996; Sacks, 2004).

Differences in mood across the spectrum of brain injury severity may correlate with different motivations for seeking treatment. At 3 months postinjury, patients with severe TBI reported being most limited by cognitive or behavioral symptoms, whereas patients with mild TBI reported being most limited by emotional disturbance (Rapoport et al., 2002). Addressing mood symptoms, therefore, may be a primary motivator for patients with mild TBI to seek treatment. Motivation for care is complex even for patients with clinical depression without comorbid brain injury (Vetter et al., 2000). Although group classifiers like injury severity may help predict why patients seek treatment, there are also fine-grained moderators (e.g., degree of adaptability) that account for within-group differences in onset of depression and recovery trajectories (Bombardier et al., 2016; Snell, Surgenor, Hay-Smith, Williman, & Siegert, 2015).

Indelible in the recovery experience for persons with persisting symptoms following mild brain injury may be incongruence between actual symptoms or functioning and expected outcome. It is our clinical experience that persons with mild injury experience incongruence between self-appraisals of actual functioning (e.g., unemployed, high symptoms) and expected functioning (e.g., expectations based on feedback from peers and providers that symptoms should be resolved). Such patients often present feeling frustrated and demoralized, which may lead to an escalation of symptoms. In this situation, it is not uncommon for patients to develop overly biased and negative appraisals of their current symptoms and associate those symptoms with inaccurate or incomplete assumptions about their injury and blame the injury for their symptoms at the exclusion of other potential contributors (Gunstad & Suhr, 2001). It is our observation that this is associated with a state of helplessness. Persisting postconcussive symptoms are strongly associated with negative mood states (Hoge et al., 2008; Iverson, Zasler, & Lange, 2007; Suhr & Gunstad, 2002b; Waldron-Perrine, Hennrick, Spencer, Pangilinan, & Bieliauskas, 2014). Cognitive behavioral techniques that include early education are effective for decreasing postconcussive symptom reporting and postconcussive disorder in part because they increase patient self-efficacy and decrease depressive symptoms (Mittenberg, DiGiulio, Perrin, & Bass, 1992; Mittenberg et al., 1996; Scheenen et al., 2017; Silverberg et al., 2013).

Diagnosis threat is another specific social–psychological risk factor for mood disturbance or impairment following milder injury, which, at its core produces negative outcomes through distorted or negative cognitions associated with the injury (Suhr & Gunstad, 2002b). It explains how simply raising awareness of an injury, and injury-related negative beliefs, can alter behavior in a negative manner on neuropsychological testing (Gunstad & Suhr, 2002; Suhr & Gunstad, 2002a). Cognitions associated with health and illnesses mediate the relationship between injury and neurocognitive outcomes (Ozen & Fernandes, 2011; Trontel, Hall, Ashendorf, & O'Connor, 2013). Malec et al. (2007) illustrated this and showed how negative illness beliefs can impact mood following brain injury.

Level of activity during recovery following brain injury may also affect mood and other outcome variables. Behavioral activation is an effective mood-enhancing cognitive behavioral technique (Dimaggio & Shahar, 2017; Nieto Fernandez & Barraca Mairal, 2017). This is true regardless of injury severity, so the timing, degree, and type of activity that maximizes mood outcomes may differ by injury severity. Early, clinically appropriate, physical activity after a mild TBI is superior to prolonged rest with regard to symptom recovery (McCrory et al., 2013; Silverberg & Iverson, 2013). Veterans who engaged in therapist-directed cognitive rehabilitation (with or without psychotherapy) showed benefits in cognitive symptoms relative to those who were asked to engage in solitary and more interpersonally passive computer-based interventions (Cooper et al., 2017).

Benefits of Rehabilitation

Post-acute interdisciplinary rehabilitation provides cognitive, vocational, and other psychosocial benefits for patients with moderate to severe brain injury (Cicerone et al., 2005; Cicerone et al., 2011; Malec & Basford, 1996; Malec et al., 1993; van Dongen et al., 2018). Fewer studies have explored mood as a primary outcome following rehabilitation in more severely injured patients (Lewis & Horn, 2017), perhaps because outcome studies for severe TBI often focus on more tangible outcomes like social reintegration and participation (Glintborg & Hansen, 2016). CBT, with both cognitive restructuring and behavioral activation components, has also proved beneficial for mood for patients with moderate to severe brain injury during post-acute recovery (Bombardier et al., 2017). In this investigation, patients with moderate to severe TBI reported fewer depressive symptoms after completing

rehabilitation; this is additional evidence that interdisciplinary treatment benefits mood for these patients (Lewis & Horn, 2017).

Our findings also suggest that interdisciplinary post-acute TBI rehabilitation has mood benefits for patients with mild TBI. Therefore, regardless of their injury severity, interdisciplinary post-acute TBI rehabilitation is mood enhancing. These data are consistent with the literature on veterans returning from combat who receive integrated rehabilitation to treat mild brain injury and comorbidities such as PTSD or depressive symptoms (Batten & Pollack, 2008; Janak et al., 2017; Management of Concussion/mTBI Working Group, 2009; Speicher et al., 2014).

Patients, regardless of injury severity, also reported significantly fewer emotionally laden symptoms of depression by the end of treatment. A significant change in emotionally laden symptoms of depression for patients with TBI between admission and dismissal increases confidence that patients experience a meaningful change in mood. With respect to specific symptoms, patients in both mild and definite TBI groups reported lower levels of dysphoria at the end of treatment. Although there was no evidence to suggest worsening mood from admission to discharge (i.e., endorsement rates of dysphoria or anhedonia did not increase over time), results warn that symptoms of anhedonia among those patients with mild TBI may be more intractable. One could speculate that patient and treatment variables could contribute to the persisting anhedonia in our mild TBI sample. Regarding patient variables, Donders and Pendery (2017) revealed a strong correlation between PHQ-9 total scores and low positive emotion for patients with TBI. The higher depressive scores in the mild TBI group, therefore, may contribute to the persistence of anhedonia in this sample. Anhedonia could also be a trait or a state characteristic (Clark, Fawcett, Salazar-Grueso, & Fawcett, 1984; Schrader, 1997). Perhaps trait-like, low positive emotion unique to our mild TBI patients, associated with their higher depressive symptoms at admission, explains their intractable anhedonia.

Treatment variables may also explain the intractable nature of anhedonia in the mild TBI group. CBT designed for mild TBI may stress cognitive therapy techniques (cognitive restructuring and reframing) at the expense of behavioral activation. Interdisciplinary treatment for definite brain injury, on the other hand, may emphasize behavioral activation more effectively through an acute focus on vocational and social reintegration goal setting. If therapists are accentuating cognitive over behavioral techniques when treating mild TBI patients, anhedonia may be treated less effectively (Dimaggio & Shahar, 2017). CBT for patients with brain injury, regardless of severity, requires a balance between cognitive therapy (cognitive restructuring) and behavioral activation (Ferguson & Mittenberg, 1996; Mittenberg, Canyock, Condit, & Patton, 2001; Mittenberg et al., 1996).

Limitations

Although patients within both TBI severity groups reported less depressive symptoms at the end of rehabilitation, the clinical significance of this finding cannot be inflated. First, the average change in scores over time is modest at best for the mild and definite groups, and persons with mild TBI remained mildly depressed at dismissal (average PHQ-9 score, 8). Patients with mild TBI also reported little improvement in positive emotion (anhedonia) between admission and dismissal. Second, several confounding variables could not be controlled because of the retrospective nature and methodology of this study (e.g., chart review of treatment seekers). This investigation did not use a cohort design and did not have a matched control group without TBI (e.g., patients with orthopedic injury). Treatments that patients received were also not standardized or manualized (e.g., CBT was not manualized). Such method and sample variance makes interpretation of between-group effects (injury severity) and within-group effects (treatment) less robust. A prospective design with a larger sample and more evenly balanced groups that controlled for important moderators of depression like self-efficacy and headache would have led to more powerful conclusions.

This study was composed mostly of well-educated, white non-Hispanic patients. While this is consistent with the demographics of our northern midwestern community, it limits generalizability of findings. Both patient-related variables (e.g., ethnicity) and provider-related variables (e.g., warmth, provider beliefs) impact treatment access and outcomes following brain injury (Fuentes, Bjornson, Christensen, Harmon, & Apkon, 2016; Fuentes et al., 2018; Meagher, Beadles, Doorey, & Charles, 2015). Patients who are vulnerable or marginalized (e.g., American Indians, Alaska Natives, Hispanics, or African Americans) have less access to treatments following brain injury due to insurance disparities or provider decision making (Fuentes et al., 2017). Compounding the problem of access, vulnerable and marginalized patients are more likely to report depressive symptoms a year or more postinjury (Perrin et al., 2014; Fuentes et al., 2016; Meagher et al., 2015).

Even though gender did not confound the relationship between injury severity and mood, our investigation could not address why treatment-seeking patients with mild TBI were more likely to be female (69% in the mild group; 37% in the definite group). Female gender is not a consistent risk factor for persistent symptoms following mild TBI (Brooks et al., 2018; Gauvin-Lepage, Friedman, Grilli, & Gagnon, 2018; Lange et al., 2013; Silverberg, Berkner, Atkins, Zafonte, & Iverson, 2016). It may simply be that men are less apt to seek treatment for mood symptoms (Seidler, Rice, Ogrodniczuk, Oliffe, & Dhillon, 2018), such as those experienced from mild TBI in the post-acute recovery, and that

women are more likely to follow through on recommended psychosocial support or treatments (Ernst et al., 2018).

Summary

Among post-acute TBI treatment seekers, patients with mild TBI reported significantly more depressive symptoms than patients with moderate or severe TBI before and after interdisciplinary rehabilitation. Injury severity appears to be an important variable to consider in treatment-seeking populations when assessing and treating patients following TBI. This finding stands in contrast to a number of studies that investigated associations between brain injury severity and mood using prospective cohort designs (Malec et al., 2007; Rapoport et al., 2002).

The present study also demonstrated that interdisciplinary rehabilitation is associated with a significant reduction in overall depressive symptoms, including dysphoria, for treatment-seeking TBI patients, regardless of injury severity. Despite the overall mood benefits of engaging in rehabilitation, a high endorsement rate of anhedonia persisted for patients with mild TBI. Why anhedonia persisted in our mild sample at the time of discharge is unknown, but it may be associated with patient-related factors (e.g., cognitive behavioral risks, social risks, more significant depression) or treatment-related factors. Regarding the latter, it was hypothesized that providers may use behavioral activation strategies more effectively with patients who have more severe brain injury. Future research should explore what patient- or treatment-related factors moderate the recovery of emotionally laden symptoms like anhedonia following brain injury.

Cognitive behavioral and other psychosocial factors likely correlate with documented differences in mood for treatment seekers across the spectrum of brain injury severity. A higher level of depressive symptoms observed in mild brain injury samples—before and after treatment—suggests that cognitive behavioral risks for depression may be particularly strong for patients with mild injury (Malec et al., 2010; Malec et al., 2007; McCrea, 2008). We illustrated how practical issues like motivation for treatment or cognitive processes such as diagnosis threat may explain some of this variance (Suhr & Gunstad, 2002a; Vetter et al., 2000).

Silverberg et al. (2013) conducted a randomized clinical trial of CBT with the goal of preventing postconcussive disorder for patients with recent injuries with cognitive behavioral risks for the condition (e.g., negative illness beliefs). Their study highlighted (1) the power of cognitive behavioral factors in precipitating and perpetuating symptoms after mild brain injury and (2) CBT as an effective treatment for reducing the risk of postconcussive disorder. Those authors also documented the superiority of CBT over a minimal standard of psychological care (education alone) in reducing postconcussive symptoms in a sample of patients at risk for postconcussive disorder. Their data also provided an understanding of why CBT was helpful in reducing the risk of postconcussive disorder. Patients who received CBT reported increasing personal control and lower levels of depressive symptoms.

The data from Silverberg et al. (2013), however, also exposed potential limitations of CBT in treating postconcussive symptoms for patients with mild brain injury. CBT had minimal anxiolytic benefits for patients with mild TBI. Targeting anxiety more effectively may indirectly help depressive symptoms and functional outcomes. Distress tolerance or exposure interventions, therefore, may need to supplement more traditional reframing and behavioral activation techniques of CBT in order to maximize treatment effects. Future research should compare CBT (with education) versus CBT in combination with distress tolerance strategies (with education) in treating patients at risk for postconcussive disorder.

Conclusion

Depression is unquestionably a problem among patients with brain injury—regardless of severity—who seek post-acute rehabilitation. Even after patients receive the clear benefits of completing post-acute interdisciplinary rehabilitation, the severity of depression continues to correlate with injury severity among treatment seekers, and patients with mild injury continue to have low positive emotion. It is imperative that interdisciplinary treatments for brain injury include psychological services to address persisting depressive symptoms. Even subtle mood or adjustment differences between subgroups of patients with brain injury highlight the importance of individualizing psychological treatments. Future investigations need to expand upon our current knowledge of which specific ingredients of therapy (e.g., reframing, behavioral activation, or distress tolerance) correlate most effectively with psychological or social outcomes for well-defined subgroups of patients with brain injury (Silverberg et al., 2013).

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Compliance with Ethical Standards

Conflict of interest Matthew R. Powell, Allen W. Brown, Danielle Klunk, Jennifer R. Geske, Kamini Krishnan, Cassie Green, Thomas F. Bergquist declare that they have no conflict of interest.

Human and Animal Rights The Mayo Clinic Institutional Review Board approved this study, which was considered to pose minimal risk to patients. The data, which consisted of patient responses to question-

naires, were collected from patient medical records and coded in a manner to ensure confidentiality; no specimens were collected.

Informed Consent For this type of study, formal consent is not required (the requirement was waived after institutional review board review).

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