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RESEARCH ARTICLE

The Mediating Role of Pain Catastrophizing: Understanding the Relationship Between Psychological Distress and Functional Disability in Mild Traumatic Brain Injury

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ABSTRACT

Background. Recovery following brain injury can be significantly impeded by the way in which an individual appraises pain, which in turn, can affect ability to cope with pain, and result in psychological distress. Pain catastrophizing, implicated in the appraisal of pain, can exacerbate the intensity of pain-related distress and impact psychological well-being. However, the concurrent evaluation of these phenomena via functional outcomes has not been examined in mild traumatic brain injury.

Material and methods. The present study evaluated de-identified archival data of 190 patients with mild traumatic brain injury following injury in motor vehicle accidents. Of primary interest was whether pain catastrophizing mediated the relationship among psychological distress (i.e., anxiety, depression) and functional disability outcomes in patients with mild traumatic brain injury.

Results. Pain catastrophizing was found to have a significant mediating effect on the relationship between anxiety and functional disability, as well as for depression and functional disability. Age, gender, time since injury, and/or pain intensity, were not significant predictors of outcome. Although, pain severity was linked to pain catastrophizing. Moreover, the current work also evaluated feigning amongst a subset of patients with mild traumatic brain injury. Interestingly, it appears that the presence of psychological distress, irrespective of the nature of that reporting, is itself predictive of functional well-being. This is an important clinical finding and supports the role of psychological factors on real-life functional compromise in patients with mild traumatic brain injury.

Conclusion. The present study found that psychological distress and functional disability are mediated by pain catastrophizing in patients with mild traumatic brain injury. It also appears that the presence of psychological distress, irrespective of the level of reported complaints (i.e., the over-reporting of symptomatology) itself, is predictive of functional well-being.

Keywords: catastrophizing, pain, depression, anxiety, disability, mild traumatic brain injury

Introduction

Traumatic brain injury (TBI) is a leading cause of death and disability globally, with the preponderance of injury related to motor vehicle incidents.[1, 2] The overall incidence of TBI per 100,000 people appears greatest in North America (and Europe), and as such, these countries experience the greatest overall burden of disease.[1] As a result of the shear force or trauma to the brain, TBI is associated with impairment in quality of life and functioning.[3] Some TBIs result in mild problems; however, mild injuries comprise 70-90% of cases and represents the majority of patients seen in hospital.[4] Mild TBI (mTBI) can lead to a preponderance of symptoms in the acute phase, including physical/somatic, cognitive, and psychological issues.[5,6] Moreover, patients continue to report having one or more symptoms after TBI insult.[7] The presence of symptoms, including pain-related phenomena, beyond three months, is considered "chronic" in nature,[8] and appears more prevalent among those having suffered mTBIs, with up to 40% of patients reporting pain beyond three months post injury.[6, 9] The experience of chronic pain has been associated with a host of negative consequences, including psychosocial distress, and low quality of life and disability.[10-12]

Though suffered physical injuries can contribute to pain, psychological factors can further exacerbate the pain experience.[13] Conversely, chronic pain can contribute to mood disturbances and negative affect.[14] The most commonly reported occurrences following mTBI include anxiety disorders and depression.[15-18] Importantly, psychological factors influence mTBI outcomes, such that psychological distress increases mTBI symptom frequency and functional disability.[19]

The ability to cope with psychological distress and pain appears to be a strong predictor of mTBI symptoms and functional well-being.[19] In particular, catastrophizing–or the cognitive distortion that overestimates the severity of a negative future event (i.e., a maladaptive coping response to pain) – is thought to exaggerate the threat value of pain.[20, 21] While pain catastrophizing alone predicts pain intensity and functional disability in chronic pain populations, pain catastrophizing and psychological distress have interactive effects that, when combined, differentially affect clinical outcomes.[22, 23] Specifically, Ullrich and colleagues showed that while psychological distress and pain severity were both independently related to functional disability, pain catastrophizing mediated this relationship and their interaction contributed a unique variance to functional disability.[22] Further, the mediating role of pain catastrophizing has been demonstrated in the relationship between depression and pain severity among older adults with chronic pain.[24] Importantly however, the role of pain catastrophizing has received little attention in the context of mTBIs. Recognizing the large population affected by mTBI, and commonly experienced psychological distress by TBI sufferers, understanding the association among pain catastrophizing and psychological vulnerabilities represents a novel avenue of exploration. Better understanding of these relationships to help reduce functioning disability, and further, be able to provide targeted treatment planning, will contribute to prosperous, long-term prognosis.

The interaction between pain catastrophizing and psychological distress has often been explained through the theoretical application of the fear avoidance model, such that painful stimuli trigger fear and catastrophizing thoughts, leading to increased pain as well as disability. Consequently, activities perceived to be painful are avoided for fear of exacerbating pain.[25] Different aspects of catastrophizing have been shown to increase pain intensity, including both difficulties shifting attention away from painful stimuli as well as excessive negative thoughts.[26] Catastrophizing also contributes to pain-related fear by exaggerating the threat value of a specific movement or behavior. Hence, individuals avoid activities thought to trigger or exacerbate pain. The avoidance of activity leads to increased negative affect, fears of pain, and perceptions of disability, all confirming expectations of low coping ability with pain.[27] Importantly, this is a bidirectional interaction, such that individuals who catastrophize pain are more likely to experience pain-related fear.[23] Conversely, negative affect, depression, and anxiety are thought to predispose individuals to catastrophize and feel fear by lowering the threshold that pain-related information is considered threatening. Negative affect is a critical factor in the early stages of pain and has been shown to predict the transition from acute to chronic conditions and associated disability up to a year later.[28]

The fear avoidance model has been applied to several health conditions.[22, 28] However, recent acknowledgements of the compatibility between this model and pain catastrophizing have galvanized attention towards the practical implications of applications to clinical populations. There is currently a paucity of literature evaluating the relationship among pain complaints, psychological distress, catastrophizing, and functional disability in individuals with mTBIs. The

goal of the present study was to examine the aforementioned relationships. Psychological distress was hypothesized to contribute a unique variance to the indices of functional disability, and as well, that pain catastrophizing would have a significant mediating effect on the psychological distress – functional disability association.

Materials and Methods

Participants

The present study evaluated de-identified archival data of 190 patients with mTBI following injury in motor vehicle accidents (MVAs; patients were either the drivers or passengers). Participants' ages ranged from 19 to 75 (M_{age} = 41.73, SD_{age} = 14.43). The sample consisted of 100 men (52.6%) and 88 women (46.3; age was missing for two participants). Participants' average years of education was 13.41 (*SD* = 3.44). The mean months elapsed between injury occurrence and the assessment was 12.9 (*SD* = 11.77). Please refer to Table 1 for demographic information. All patients were undergoing assessment for the purposes of recommendations for remediation and/or receiving therapy for lingering symptoms. Participants were included if they were adults over age 18, English speaking, and having sustained a mTBI, defined as a Glasgow Coma Scale (GCS) score of 13 to 15, loss of consciousness (LOC) less than 30 minutes, and PTA less than 24 hours.[29] Moreover, chronic physical pain was operationalized as the average pain intensity rating of greater than or equal to 5 on a 0-10 on the Visual Analogue Scale for Pain with duration of chronic pain 3 months or more (with the average length of experienced pain being greater than 12 months), and the endorsement of experienced pain on a continuous basis (i.e., daily) leading up to the assessment.

Exclusion criteria were current and uncontrolled substance use, psychiatric illness (i.e., Schizophrenia or other psychosis), and/or diagnosed, pre-existent psychological conditions commonly observed in this population (i.e., depression, bipolar disorder, anxiety, phobias, generalized anxiety, adjustment disorders), neurological conditions (including headache), developmental disorders, and multiple head traumas (including more than one concussion). Patients also completed the Structured Inventory of Malingered Symptomatology (SIMS). Thirty point five percent of the sample (of the 190 patients, 133 completed the SIMS) appeared to have over-reported symptomatology as indicated by the Total SIMS score (please refer to the 'Measures' section for further questionnaire details). There is a vast literature that has evaluated exaggerated psychological symptom self-report in mTBI.[30] The inclusion of this measure in subsequent analyses was felt important to provide the most accurate picture of the relationships among measures of interest. As little research has been done looking at these variables per se, the analysis of the effect of the SIMS was exploratory.

The study was approved by a university Research Ethics Board.

Table 1: Sample Demographics

Demographic Characteristic	Descriptives
Age (Years)	
Mean (SD)	41.73 (14.43)
Range	19.0 - 75.0
Gender, n (%)	
Men	100 (52.6%)
Women	88 (46.3%)
Months From Accident to Assessment	
Mean (SD)	12.19 (11.07)
Range	12 months - 55 months
Education (Years)	
Mean (SD)	13.41 (3.44)
Range	10.0 - 26.0 years

[a] Gender information was missing for two patients.

Measures

Pain Catastrophizing Scale (PCS). The PCS is a 13-item questionnaire comprising three subscales that measure dimensions of pain catastrophizing, including rumination, magnification, and helplessness – which provides for a computed, total catastrophizing score. Frequency of catastrophizing thoughts are rated on a 5-point Likert scale ranging

from 1 (*Not at all*) to 5 (*All the time*), with higher scores indicative of greater pain-related catastrophizing thoughts. A total PCS score of 30 (or more; above 75th percentile) have been consistently correlated with more frequent pain-related catastrophic thinking, and higher levels of psychological distress.[31, 32] The PCS has adequate to excellent internal validity and is a reliable measure of pain catastrophizing.[32] Its use is well-documented in pain populations, including mTBI, postoperative pain, soft-tissue injuries, and fibromyalgia. [21, 33, 34]

Beck Anxiety Inventory (BAI). The BAI is a self-report scale measuring anxiety symptom severity in adults over age 17.[35] The 21-item measure assesses somatic and cognitive symptoms of anxiety, with responses rated on a 4-point Likert scale of severity. Total possible scores range from 0 to 3, with clinical cut-offs describing minimal anxiety (<7), mild anxiety (8-15), moderate anxiety (16-25), and severe anxiety (>26). Psychometric evaluations of the BAI have demonstrated a high level of internal consistency (Cronbach's α =.92), and good test-test reliability.[36] Subfactors of the BAI have been shown to be useful in the differentiation of specific anxiety disorders, [35] as well as differentiating anxiety from depression.[37]

Beck Depression Inventory-2nd Edition (BDI-II). The BDI-II is a self-report scale measuring depressive symptom severity in individuals over the age of 13.[38] It contains 21 items that correspond to the diagnostic criteria for major depressive disorder outlined in the Diagnostic and Statistical Manual for Mental Disorders V.[39] Items are rated on a 4-point Likert scale, ranging from 0 to 3, with higher scores indicating higher levels of depression. The scale instructs respondents to endorse statements characterizing how they have been feeling over the past two weeks. Potential total scores range from 0 to 63, with scores of <13, 14-19, and 20-28, indicating minimal, mild, and severe depression, respectively. The BDI-II has demonstrated good internal consistency (α = 0.9) and has been shown to be a reliable measure of depressive symptoms (re-test reliability ranging from .73-.96).[40] Additionally, it has been validated in chronic pain populations.[41]

Visual Analogue Scale for Pain (VAS). To measure pain severity, a visual analogue scale adapted for pain measurement was used.[42] A 10cm scale is presented ranging from 0 *(No pain*) to 10 (*Pain as bad as it possibly can be*) to assess current pain severity. The use of visual analogue scales for pain measurement have been found to have high test-retest reliability and to be a valid and responsive measure of pain intensity.[43]

Pain Disability Index (PDI). The PDI is a 7-item questionnaire measuring the perceived effect of pain on one's ability to perform everyday tasks, beyond the effect of pain severity.[44] The PDI measures level of disability in areas of life such as family/home responsibilities, self-care, recreation, social life, occupation, and sexual behaviour. Item responses are made on a scale of 0 (*No disability*) to 10 (*Worst disability*). Possible scores range from 0 to 70, with higher total scores indicating greater pain-related disability. The PDI has demonstrated modest test-retest reliability, good validity, and internal reliability.[44, 45]

Structured Inventory of Malingered Symptomatology (SIMS). The SIMS is a 75-item true/false measure intended for use with individuals at least 18 years of age.[46] The self-report measure is used to assess feigned symptoms across 5 independent subscales: Psychosis, Neurologic Impairment, Amnesic Disorders, Low Intelligence, and Affective Disorders. Question responses are coded as either 1 (*True*) or 2 (*False*). The total composite score, which has been found to be an adequate validity indicator,[47] is calculated by summing the raw subscale scores, with possible scores ranging from 0 to 75. A total score greater than 14 indicates the possibility of symptom exaggeration. The SIMS has been shown to demonstrate both convergent validity and incremental validity in comparison to clinical judgement based on interviews and/or record data alone.[48, 49]

Please refer to Table 2 for the means and SD of all self-reported measures.

Table 2: Study variables for self-reported measures

Variable	Mean	SD	Range
PCS	34.91	11.4	0 - 52
BAI	27.1	14.0	0 - 60
BDI-II	30.76	12.79	2 - 63
PDI	43.76	13.86	0 - 69
VAS	6.70	1.71	0 - 10
SIMS	21.44	9.53	2 - 49

Statistical Analyses

All analyses were performed using R Statistical Software (v4. 2. 0).[50] To describe the demographic characteristics of the patients, mean (SD), and range were presented in Table 1. Correlation analyses using Pearson correlation were used to test statistical associations between all predictor and outcome variables. Further correlation analyses were performed between demographic (i.e., gender, age), clinical characteristics (i.e., months elapsed from injury to assessment) and functional disability to assess suitability for inclusion as potential covariates in further analyses. Rationale for this process was derived from previous analogous research [24] Extending on this empirical rationale, three linear regressions were conducted to establish whether the demographic or clinical variables significantly predicted functional disability outcomes to further justify inclusion as covariates. Preliminary analyses were conducted to check the assumptions of normality, linearity, homoscedasticity, and multicollinearity. Two separate linear regressions were conducted to evaluate whether anxiety and depressive symptoms were significant predictors of functional disability in mTBI patients. Hierarchical regressions were conducted to evaluate whether participants' SIMS scores accounted for a significant amount of variance in functional disability, above and beyond anxiety and depressive scores alone for the purpose of justifying participant exclusion.

Tests of mediation were used to evaluate whether pain catastrophizing mediated the associations among pain severity, psychological distress, and pain-related functional disability. Statistical significance was set at $p = .05$. Tests of mediation were conducted using the sem package in R version 3.1-15, [51] using 10,000 bootstrap samples at 95% confidence intervals, with significant set at $p < .05$. Missing data for the primary variables were minimal (1.58% to 3.68%).

Results

Analyses

Correlational analyses were first conducted to establish whether there were significant associations between the primary variables. The means, standard deviations, and correlations among the primary variables are presented in Table 3.

Table 3: Means, Standard Deviations, and Correlations with Confidence Intervals Among the Primary Variables

Variable	*M*	*SD*	1	2	3
1.Pain Catastrophizing	34.91	11.40			
2.Functional Disability	43.76	13.86	.66** [.56, .73]		
3.Anxiety	27.10	14.00	.65** [.56, .73]	.55**[.44, .64]	
4.Depression	30.76	12.79	.70** [.62, .77]	.58**[.48, .67]	.74** [.67, .80]

[b] *M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. * Indicates $p < .05$. ** indicates $p < .01$.

Further correlational analyses were conducted to identify whether there were significant associations between demographic characteristics (i.e., age, gender), clinical considerations (i.e., months from the time of injury to the assessment), and the primary outcome variable, functional disability. Table 4 includes means, standard deviations, and correlations among the demographic and clinical variables, and functional disability. Results of these analyses indicated that gender and months to assessment were not significantly associated with functional disability. While statistically significant, age appeared to only have a small correlation with functional disability, $r = .20$, $p < .01$, 95% CI [.05, .34].

Table 4: Means, Standard Deviations, and Correlations with Confidence Intervals among Demographic and Clinical Variables and Outcome Variable

Variable	*M*	*SD*	1	2	3
1. Age	41.73	14.43			
2. Gender	1.47	0.50	.03 [-.11, .18]		
3. Months to Assessment	12.19	11.07	.03 [-.11, .18]	-.02 [-.17, .13]	
4. Functional Disability	43.76	13.86	.20** [.05, .34]	.06 [-.09, .20]	.09 [-.06, .23]

[c] *M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. * indicates $p < .05$. ** indicates $p < .01$.

To further explore the relationship between these variables and functional disability, three linear regressions were conducted examining whether age, gender, and months to assessment predicted functional disability, respectively. Results did not support gender, $b = -2.55$, $t(181) = -1.24$, $p = .216$, 95% CI [-6.60, 1.50], $\beta = -.09$, $R^2 < 0$, age, $b = .04$, $t(178) = 0.52$, $p = .604$, 95% CI [-.10, .18], $\beta = .04$, $R^2 < 0$, or months to assessment, $b = .12$, $t(169) = 1.22$, $p = .226$, 95% CI [-.07, .31], $\beta = .09$, $R^2 < 0$, as significant predictors of functional disability outcomes. Based on the findings from both the regression and correlation analyses, and in line with previous research practices, [24] gender, age and months to assessment were not included in further analyses as confounding variables.

A SIMS composite total score above 14 have been suggested to indicate the possibility of significant symptom exaggeration. However, the most recent review has posited that when using the common cut-off score, the SIMS may not reliably distinguish feigned psychopathology from severe manifestations of genuine psychiatric illness.[48] Based on this work, statistical analyses were conducted to determine whether the SIMS score accounted for significant additional variance in functional disability outcomes, above psychological distress symptoms alone, to determine whether patient exclusion would be required for further analyses. Two hierarchical regressions were carried out to examine the additional variance of SIMS scores inclusion in models testing the predictive value of anxiety (model 1) and depression symptoms (model 2) on functional disability outcomes. Patients with SIMS total scores under 14 were coded as 1 ($n = 35$), and 14 and above were coded as 2 ($n = 98$).

For the first hierarchical regression, step 1 testing the predictive value of anxiety symptoms on functional disability outcomes, indicated that anxiety symptoms were a significant predictor of functional disability, $b = .54$, $SE = .07$, $t(180) = 8.69$, $p < .001$, 95% CI [.42, .68], $\beta = 54$. Further, the inclusion of anxiety symptoms as a predictor contributed significantly to the regression model, $F(1,155) = 67.16$, $p < .001$, and accounted for 28.96% (adjusted R^2 value) of the variance in functional disability. Step 2 included the SIMS variable, evaluating whether the inclusion of the variable accounted for significant additional variance in functional disability outcomes above anxiety symptoms alone. Results of this analysis revealed that SIMS scores were not a significant predictor of functional disability, $b = 4.07$, $SE = 2.76$, $t(180) = 1.47$, $p = .144$. Although the regression model including SIMS acceptability was significant, $F(2,179) = 38.31$, $p < .001$, the inclusion of this variable contributed little additional explained variance in functional disability, $R^2 = .2919$. Importantly, the (lack of) change in R^2 by adding SIMS acceptability to the model was not significant, $F(1,179) = 1.58$, $p = .21$.

Similar to the first model, our second hierarchical regression model first tested the predictive value of depressive symptoms on functional disability outcomes. Results of this analysis indicated that depressive symptoms were a significant predictor of functional disability $b = .64$, SE = .06, $t(180) = 9.67$, $p < .001$, 95% CI [.51, .77], $\beta = .58$. Further, these symptoms contributed significantly to the regression model, $F(1,180) = 93.57$, $p < .001$, and accounted for 34% (adjusted R^2 value reported) of the variance in functional disability. Step 2 of the hierarchical regression, including SIMS scores, was statistically significant, $F(2,179) = 47.69$, $p < .001$. However, SIMS scores contributed little additional explained

variance (i.e., R^2 = 34.03%) in functional disability outcomes above depressive symptoms alone. Additionally, the change in R^2 with the inclusion of the SIMS as a predictive variable to the model, was not significant, $F(1,179) = 1.53$, $p = .22$. Together, based on the lack of additional variance in functional disability outcomes accounted for by the inclusion of SIMS scores in both models, participants with SIMS scores 14 and above were not excluded from further analyses.

Previous research has also demonstrated the role of pain severity in the relationship between pain catastrophizing and depressive symptoms.[24] Based on these findings, further analyses explored whether pain severity significantly correlated with any of the primary variables. Results of these correlational analyses revealed that pain severity was not significantly correlated with functional disability, $r(183) = .05$, $p = .53$, anxiety, $r(185) = -.02$, $p = .81$, or depressive symptoms, $r(184) = .03$, $p = .71$. There was a weak (positive) correlation between pain severity and pain catastrophizing, $r(188) = .20$, $p = .005$.

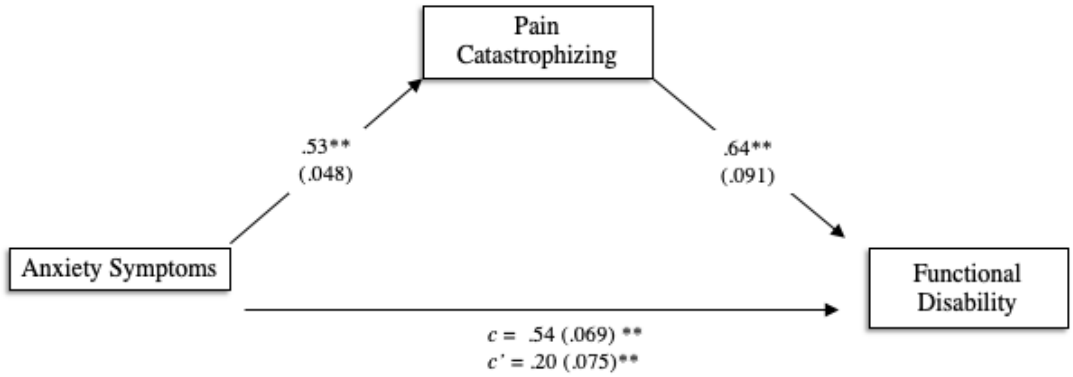
To further examine whether pain severity significantly influenced functional disability outcomes, we conducted a follow-up linear regression model. Results of this analysis suggested that pain severity was not a significant predictor of functional disability, $b = .006$, $SE = .009$, $t(183) = .624$, $p = .534$. Further, the overall model was not significant, $F(1, 183) = .39$, $p = .53$, $R^2 = -.003$. Based on these findings, pain severity was not considered in further analyses.

Statistical assumptions for step 1 of both model 1 and model 2 linear regressions were run, including normality, linearity, and homoscedasticity. Normality was assessed using the Shapiro-Wilk's test, which revealed a non-significant p-value ($p = .19$) for model 1, while the test's associated p-value for model 2 was significant ($p = .02$). However, the Q-Q plots for both models showed that the points fell approximately along the reference line indicating that normality could be assumed. Linearity was assessed using the Tukey test, which yielded a non-significant p-value for model 1 ($p = .26$), and a significant p-value for model 2 ($p = .003$). Visual inspections of the Pearson residuals scatter plots against the predictor variables and fitted values demonstrated slight curvature. However, it appeared to be influenced by sparse data points falling outside of the expected range. Though the removal of significant outliers can often correct for violations of linearity, this proposed fix incorporates greater researcher degrees of freedom. Recognizing this trade-off, and in favour of including the full dataset, outliers were not removed, and further statistical corrections were not made. Homoscedasticity was assessed using the non-constant variance test. The test had significant p-values associated with model 1 ($p < .05$), and model 2 ($p = .022$). To rectify the homoscedasticity violation, we applied a sandwich variance estimator to correct the models' standard errors. Adjusted robust standard errors are reported.

Of primary interest was whether pain catastrophizing mediates the relationship between psychological distress (i.e., anxiety, depression) and functional disability outcomes in patients with mTBI. To address these goals, two mediation analyses were conducted: first to address pain catastrophizing in relation to anxiety symptoms and functional disability, and the second to address pain catastrophizing in relation to depressive symptoms and functional disability.

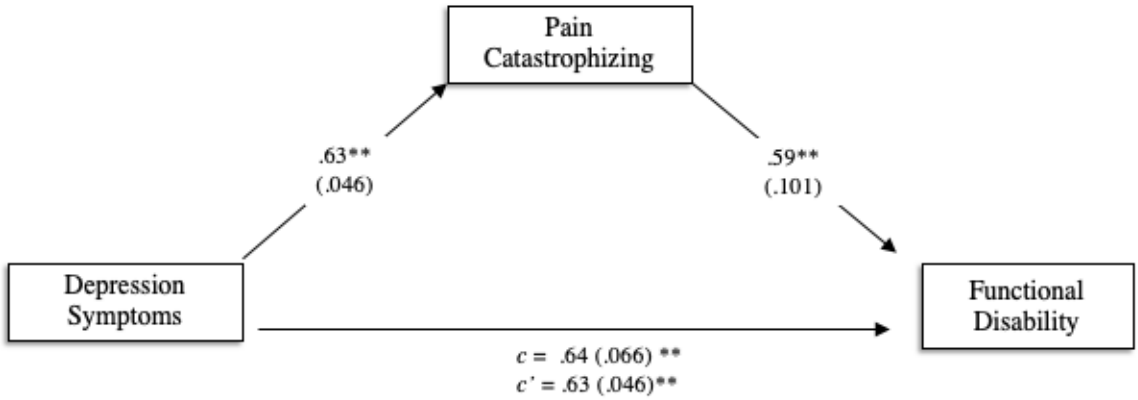
Using 10,000 percentile bootstrapped samples to test for a significant indirect effect, results supported the mediating role of pain catastrophizing in the relationship between both anxiety and functional disability outcomes, $B = .34$, $SE = .055$, 95% CI [-.00, .39], $p < .001$ (see Figure 1), and depression and functional disability outcomes, $B = .37$, $SE = .07$, 95% CI [.24, .51], $p < .001$ (see Figure 2). Pain catastrophizing was significantly correlated with anxiety, depression, and functional disability (see Table 3).

Figure 1: Model Showing the Effect of Anxiety Symptoms on Functional Disability Through Pain Catastrophizing



[d]** = $p < .001$. Indirect effect: $B = .34$, $SE = .055$, $p < .001$.

Figure 2: Model Showing the Effect of Depression Symptoms on Functional Disability Through Pain Catastrophizing



[e]** = $p < .001$. Indirect effect: $B = .37$, $SE = .07$, $p < .001$.

Discussion

This study sought to better understand the association between psychological distress (i.e., anxiety and/ or depression) and functional disability in patients with mTBI with chronic pain, and to evaluate the degree to which this relationship may be mediated by pain catastrophizing. It was found that anxiety, depression, and functional disability were linked, and that pain catastrophizing mediated the relationships between psychological distress and functional outcomes. Moreover, the level of pain (i.e., pain intensity) appears not to be correlated with psychological well-being or functional disability. Although greater pain intensity (i.e., a weak connection) was associated with higher levels of pain catastrophizing. That pain catastrophizing functions as a mediator represents novel research and is likely to help elucidate the psychological distress – functional disability relationship.

Interestingly, these findings run counter to previous research supporting the relationship between pain severity and psychological distress symptoms,[24] but appear consistent with the extant research on pain catastrophizing, which has demonstrated that pain catastrophizing increases reported pain intensity.[32] Even so, other research has indicated that pain severity appear less important in the maintenance of chronic pain and long-term disability than psychological and cognitive-behavioural factors.[52-54] The present work inferentially appears to partially support the fear avoidance model of pain; that is, the model suggests that a painful stimulus triggers fear and catastrophizing thoughts, consequently increasing pain and disability. And the bidirectional nature of

the model – leads to avoidance of activities believed to exacerbate pain.[55]

The current results support and extend previous findings demonstrating the role of psychological factors in coping among patients with mTBI. Specifically, psychological distress and catastrophic appraisal about pain appear to have stronger associations with functional outcome than pain intensity. There is also evidence that avoidance can occur without pain-related fear such that inactivity and disuse also contribute to pain in chronic conditions.[28] This pathway is driven by depression, which promotes apathy and demotivation, to reduce activity in the absence of fear. In the presence of pain, negative affect triggers catastrophizing that further exacerbates negative affect, pain, and promotes inactivity. Hence, the mediating effect that catastrophizing has on psychological distress and functional disability, also appears to align with the depression/apathy model.

A range of psychiatric disorders can develop acutely and persist long-term in mTBI, irrespective of injury severity.[56] While much of the extant literature has focused on the nature of post-traumatic stress and depression that develops after TBI, anxiety disorders are one of the most frequently documented post-injury psychiatric changes in patients with TBI with prevalence rates ranging up to 70%.[57] It is thus surprising that only a handful of literature reviews have examined the association between TBI and anxiety disorders.[57-61] Findings by Mayou and associates[62] suggest that anxiety is an outcome that is particularly disabling for persons who sustain a TBI. Thus, it is relatively common for TBI to lead to the development of anxiety disorders, and it is essential for healthcare providers to become familiar with their characteristics in this specific population. At this time, the current data are not sufficient to distinguish amongst the stressors experienced by the patients with mTBI, nor whether their interaction creates a unique effect as linked to pain-related functional disability. Several published studies have identified PCS scores as a unique predictor of pain intensity and pain-related functional disability in a variety of pain conditions, independent of measures of anxiety and depression.[21, 32, 53] More recently though, Sturgeon, Ziadni, Trost, Darnall, and Mackey[54] found in individuals with chronic pain through structural path modeling that pain-related interference in daily life and depressive symptoms are related to broad pain-relevant variables (e.g., pain intensity, maladaptive appraisal patterns related to pain, including catastrophizing). However, anxiety was not included in their model. Overall, the extant literature speaks to the need for more research to better understand the nuanced relationship between pain catastrophizing, psychological distress symptoms and particularly that for anxiety, and functional disability.

Duration of time between injury onset and evaluation, age of the patient at the time of evaluation, and whether the individual was male or female, did not impact functional disability. Studies have found that sex versus age appears more predictive of functional decline. For example, Levin and colleagues[63] found in 2000 patients with mTBI that middle aged woman (versus a younger cohort or those over 50 years of age) had worse somatic symptoms. Symptoms overall were also worse in women as compared to men. The authors concluded that women are more vulnerable to post-concussive symptoms and somatic issues although further evaluation was deemed necessary to confirm these findings.

The current work also evaluated SIMS performance amongst a subset of the patients with mTBI. Published literature in mTBI has focused on validity indicators (symptom and performance-based indices) as related to either cognitive performance and/or psychological complaints; however, the evaluation of functional recovery appears to have been looked at via reduction of self-reported post-concussive symptoms post-injury, or the scores from the Glasgow Coma Scale.[64] To this authors knowledge, there are no published works that have used an objective measure to decipher whether symptom reporting reflects true psychological limitations. Hence, the evaluation of the SIMS in the current context is a novel approach. Interestingly, the SIMS total composite score, which is sensitive to feigning, was not a significant predictor of outcome. Thus, it appears that the presence of psychological distress, irrespective of the nature of that reporting, is itself predictive of functional well-being. This is an important clinical finding and supports the role of psychological factors on real-life functional compromise in patients with mTBI, and as well, supports neurorehabilitation efforts that focus on reducing distress (such as provision of cognitive behaviour therapy) and improving quality of life for these individuals.

Limitations

The current work has several limitations that could serve as potential avenues for future research. Notably, the measure used to operationalize pain severity symptoms, the VAS, rates pain intensity in the moment, while the BDI-II and BAI measure depressive symptoms over the

past two weeks and anxiety symptoms over the past month, respectively. Given symptoms can fluctuate throughout and across time, the different noted timepoints for recording symptom presentation, creates a challenge for comparability. This may perhaps explain why pain severity was weakly associated with catastrophizing, and not related to psychological distress, or functional disability. Even so, some may consider the evaluation of these variables as, "current" symptom complaints that speak to functioning in the "here and now" (versus how one may have been functioning directly following the subject accident). Even so, future research may want to consider the adaptation of measures that have coinciding timelines to better map onto the psychological and pain-related phenomena of interest.

The current study also utilized a cross-sectional design. While this design permits an increased and diverse sample size, it restricts the ability to make causal inferences on psychological distress, catastrophizing, and disability. However, evidence for fear avoidance as a causal factor is mixed; as such, more prospective studies are deemed necessary to answer this question.[28] Moreover, the use of self-report measures versus taking an interview/ diagnostic approach is another limitation of the study.

Further, while we collected patients' data on prescribed medication usage, diagnosed comorbidities following the subject accident, and types of pain experienced, these factors were not the focus of the current study.

Conclusions

The current, novel findings suggest that psychological distress and functional disability are mediated by pain catastrophizing in patients with mTBI. It also appears that the presence of psychological distress, irrespective of the level of reported complaints (i.e., the over-reporting of symptomatology) itself, is predictive of functional well-being. Future studies that evaluate causality, and more specifically whether additional measures of mood (e.g., anxiety) help to elucidate which variables play a role in functional outcomes should be conducted. Focusing on pain catastrophizing sheds light on a potentially influential psychological variable that deserves attention in the provision of treatment to help reduce the pain experience and in turn provide for improved psychological well-being and quality of life.

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