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The Influence of Pain on the Development of PTSD Across the Acute Post Trauma Period

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College Honors Thesis

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Abstract

Exposure to potentially traumatic events is fairly common among US adults, yet only a small fraction develops post-traumatic stress disorder (PTSD). It is unclear, however, why some individuals develop PTSD and others do not. Higher pain after a traumatic injury has been associated with higher PTSD symptomology and may be a risk factor for developing PTSD. However, few studies have examined symptoms during the period immediately after a trauma to determine how they relate to PTSD outcome. The goal of this study was to identify trajectories of pain throughout the first month after a traumatic injury and examine their relation to PTSD symptoms at 1 month. A sample of (n = 88) individuals who had experienced a traumatic injury assessed their pain through daily mobile assessments for the first month after injury. Daily mobile assessments consisted of self-report surveys sent to the participants' mobile device. A follow-up interview was conducted at 1 month after injury to assess PTSD symptomology. Using growth mixture modeling, three trajectories of pain were identified: low pain, decreasing pain, and persistent high pain. Membership to the low pain group was associated with lower PTSD, depression and disability symptoms at 1 month after injury. Membership to the high pain group was associated with higher levels of PTSD, depression and disability symptoms at 1 month. These results demonstrate that there are distinct trajectories of pain after a traumatic injury and these trajectories may relate to later symptoms of psychopathology.

The Influence of Pain on the Development of PTSD Across the Acute Post Trauma Period

The overwhelming majority of adults (89.7%) in the US will experience a potentially traumatic event (PTE) in their lifetime (Kilpatrick et al., 2013). A significant portion (8.3%) will develop posttraumatic stress disorder (PTSD). PTSD is associated with several negative outcomes—including an inability to work, impaired social relationships, dependence on others, and anxiety and depression (O'Donnell et al., 2013). Thus, preventing the onset of PTSD is of great public health importance. An important first step in understanding how to prevent PTSD is to identify the factors that contribute to its development. One such factor that is posited to be highly relevant to the onset of PTSD is pain.

Posttraumatic stress disorder (PTSD) is defined by the Diagnostic and Statistical Manual of Mental Disorders 5 (*DSM-5)* as a response to a traumatic event that involves direct exposure or witnessing in person actual or threatened death, serious injury or sexual violence. PTSD is diagnosed when a response includes re-experiencing symptoms; persistent avoidance of stimuli associated with the event; negative alterations to cognitions and mood; and marked alterations in arousal and reactivity (American Psychiatric Association, 2013). A period of 1 month is required to pass since the event for a diagnosis to be made (American Psychiatric Association, 2013). Since PTSD cannot be diagnosed until 1 month after the event, the first month after trauma—referred to as the acute post trauma period—may be a crucial period for the development of PTSD symptoms. Whitman, North, Downs, & Spitznagel (2013) examined the development of PTSD symptoms within the first month. They found that reexperiencing, arousal and avoidance symptoms emerged rapidly throughout the first few weeks after trauma and that avoidance best predicted PTSD diagnosis at 1 month. Their results suggest that there are changes that rapidly occur in the first month after a traumatic injury and that affect the development of PTSD. The role that other factors, such as pain, may play a role in the development of these symptoms within this first month has not yet been explored.

Pain as a Factor in the Development of PTSD

Prior research has suggested that physical symptoms, including pain, after trauma may predict the development of PTSD symptoms. Pain in the hospital was significantly related to PTSD symptoms in both adults and children after a PTE (Archer et al., 2016; Hildenbrand, Marsac, Daly, Chute, & Kassam-Adams, 2016; Norman, Stein, Dimsdale, & Hoyt, 2008). Hildenbrand et al. (2016) studied the relationship between pain and posttraumatic stress symptoms in youth post injury. Elevated pain within the first few weeks after trauma was associated with greater posttraumatic stress symptoms at 6 months. Additionally, Norman et al. (2008) found that elevated pain 24 to 48 hours after a traumatic injury increased the odds of developing PTSD 4 months later by more than fivefold and 8 months later by almost sevenfold. Similarly, pain intensity at hospital discharge was significantly correlated with depressive and PTSD symptoms at 1 year after a traumatic injury (Archer et al., 2016). Therefore, the experience of pain at the time of the trauma is associated with later symptoms of psychopathology.

The mutual maintenance model proposed by Sharp and Harvey (2001) suggests a possible mechanism connecting pain and PTSD. Many studies have shown that pain and PTSD often present together after a traumatic injury (Liedl et al., 2010; Sharp & Harvey, 2001; Ullrich et al., 2013). In a sample of veterans in rehabilitation for a spinal cord injury, 31% had both PTSD and pain, while 25% had pain without PTSD and 14% had PTSD without pain (Ullrich et al., 2013). Due to this high comorbidity of pain and PTSD, Sharp and Harvey (2001) propose that pain and PTSD are mutually maintaining conditions; they propose seven factors common to pain and PTSD that increase distress and impairment and serve to perpetuate both conditions. These seven contributing factors include: attentional biases, anxiety sensitivity, reminders of the event, avoidance symptoms, depression, anxiety and pain perception, and cognitive demand (Sharp & Harvey, 2001). Liedl et al. (2010) provided support for this model. Higher levels of pain at one week after trauma predicted higher arousal symptoms at 3 months. Elevated arousal at 3 months then predicted higher pain at 12 months. Further, higher pain at 3 months following a traumatic injury was associated with higher re-experiencing, arousal and avoidance symptoms of PTSD at 12 months (Liedl et al., 2010). Therefore, pain and PTSD symptoms after a traumatic injury are intimately linked, where higher symptoms of pain may lead to higher symptoms of PTSD. This suggests that pain and PTSD impact each other's development over time.

Since elevated pain may relate to later PTSD, it has been suggested that treating pain shortly after injury may also reduce or prevent PTSD (Bryant, Creamer, O'Donnell, Silove, & McFarlane, 2009; Holbrook, Galarneau, Dye, Quinn, & Dougherty, 2010). Across a sample of injured military personnel, the use of morphine after trauma was associated with a lower risk of PTSD 24 months after injury (Holbrook et al., 2010). Morphine administration shortly after trauma was associated with a lower risk of PTSD after injury compared to those who did not receive morphine (Holbrook et al., 2010). Similarly, in a sample of patients in the hospital after a traumatic injury, those who were diagnosed with PTSD at 3 months received significantly less morphine than those who did not develop PTSD, and acute pain levels predicted later PTSD (Bryant et al., 2009). It is hypothesized that morphine may interfere with memory consolidation after a traumatic injury through relieving pain (Bryant et al., 2009; Holbrook et al., 2010). Further, the mutual maintenance model—as supported by Liedl et al. (2010)—suggests that lowering early pain may reduce later PTSD symptomology and reducing early re-experiencing symptoms may lower later pain. Therefore, the efficacy of these pharmacological interventions in lowering the risk of PTSD supports an interaction between early pain and PTSD symptoms following a traumatic event.

Pain after Trauma Changes over Time

The majority of the studies that examined the association between pain and PTSD have used a single assessment of pain and later outcomes. Pain, especially in the case of an injury, may be present for an extended period of time. Additionally, the pain intensity may vary and these variations in pain may differentially relate to subsequent outcomes. For instance, those who experience elevated pain for weeks after a trauma may be at greater risk for maladaptive outcomes such as PTSD than those whose pain quickly declines after the trauma. Prior studies have indicated that higher levels of pain after a traumatic injury are associated with a greater risk of developing PTSD (Hildenbrand et al., 2016; Norman et al, 2008). However, these studies do not examine pain over time and so it is unclear whether it is the high level of initial pain or a persistent trend of high pain that increases the risk of PTSD.

There is some evidence to suggest that sustained pain may be important in determining later psychopathology. Chapman, Fosnocht, and Donaldson (2012) found that a trajectory of pain in the first six days after hospital discharge provided more precise information about the experience of pain than an individual assessment. Specifically, looking at pain over time measures both pain intensity and the rate of resolution whereas individual assessments only measure pain intensity. In the first week after a traumatic injury, patients showed varying rates of pain resolution or increase over time (Chapman et al., 2012). These different rates of change may be informative for examining the efficacy of pain management post trauma (Chapman et al., 2012). Additionally, since prior studies have shown a relation between pain and PTSD, the pain trajectory may be a useful metric for more specifically examining its effect on the development of PTSD.

The few studies that have looked at the interaction between trajectories of pain and other outcomes after injury have supported a relation between lower courses of pain and lower PTSD symptomology. One study looked at the course of pain after a traumatic injury over the first year after a whiplash injury (Sterling, Hendrikz, & Kenardy, 2011) Three trajectories were identified: 45% belonged to a mild trajectory—in which pain started off mild and slowly reduced throughout one year—39% to a moderate trajectory—in which pain remained at a moderate level—and 16% to a chronic or severe trajectory—in which a high level of pain persisted throughout the year (Sterling et al., 2011). Additionally, Sterling et al., (2011) found that 75% of individuals in the low neck pain trajectory had a low prevalence of PTSD symptoms in the first year after injury. Further, Sawyer et al. (2015) identified four trajectories of headache pain over the 12 months following a mild traumatic brain injury. None of the individuals in the resolved and improving pain trajectories had PTSD at 1 year (Sawyer et al., 2015). Taken together, these studies suggest that a low trajectory of pain after a traumatic injury may lead to better outcomes and higher pain trajectories may lead to higher PTSD symptomology.

Since both PTSD and pain can lead to deleterious long-term health outcomes, it is crucial to identify symptoms early on in order to improve overall recovery. Considering the clinical relevance of early identification of symptoms, examining pain trajectories within the acute post trauma period may inform how pain is associated with the risk for PTSD and provide information to help with pain management and reduction of PTSD. Further, no prior studies have examined how the course of pain throughout this first month may affect the risk of developing

PTSD symptomology. Therefore, the goal of this study was to determine the presence of varying trajectories of pain within this first month period and how they relate to risk of PTSD at 1 month.

The current project examined the relation between the course of pain throughout the acute post trauma period and PTSD symptoms. First, pain trajectories during the first month of the trauma were identified. It was hypothesized that three classes of pain would be identified: constant low level of pain, initial moderate and decreasing pain, and constant chronic pain. Second, associations between membership to a specific pain trajectory class and PTSD symptoms one month after the event were examined. It was hypothesized that persistent elevated pain would be associated with greater PTSD symptom severity and persistent low level of pain would be related to lower PTSD symptom severity.

Methods

Participants

Participants were 88 individuals who had gone to the University of Vermont Medical Center for treatment of a traumatic injury. Traumatic injury types included motor vehicle accidents (n = 43, 48.9%), assault (n = 1, 1.1%), recreational injury (n = 11, 12.5%), work accident (n = 6, 6.8%), fall (n = 12, 13.6%), crush injury (n = 2, 2.3%), and burn (n = 8, 9.1%). Participants were *M* = 35.02, *SD* = 10.52 years old. The majority of participants were male (n = 55, 62.5%). All participants reported that they were non-Latino, with two participants not reporting ethnicity. The majority of the sample was White (n = 78, 88.6%). The rest self-identified as African-American (n = 4, 4.5%), Asian American (n = 1, 1.1%), Pacific Islander (n = 1, 1.1%), American Indian (n = 2, 2.3), and Biracial (n = 2, 2.3%). The majority of the sample earn a household income below $50,000 (n = 52.4%).

Measures

Numeric Pain Rating Scale: The Numeric Pain Rating Scale is a tool used to measure one's level of pain. The scale ranges from 0 (no pain) to 10 (worst pain imaginable). This measure is widely used and has been tested against others to show validity (Hawker, Mian, Kendzerska, & French, 2011).

PTSD Checklist-5 (PCL; Blevins, Weathers, Davis, Witte, & Domino, 2015): The PCL is a 20-item self-report measure that assesses PTSD symptoms according to DSM 5 criteria experienced over the last month. It assesses symptoms across 4 symptom clusters of PTSD (re-experiencing, negative mood, avoidance, and hyperarousal) on a 0-4 point Likert scale. Total scores range from 0-80. There was high internal consistency ($\alpha = .938$).

Patient Health Questionnaire-8 (PHQ-8; Kroenke, Spitzer, & Williams, 2001): The PHQ-8 is an 8-item self-report measure that assesses depression symptoms experienced in the last two weeks. Ratings are made on a 0-3 point scale with regards to the frequency with which a symptom has been experienced. Scores range from 0-24, with higher scores indicating more severe depression. The PHQ-8 is adapted from the PHQ-9 and is identical except for the removal of an item on suicidal ideation. There was high internal consistency ($\alpha = .883$).

Sheehan Disability Score (SDS; Sheehan, 1983): The SDS was developed as a global measure of the impact of mental illness on functioning. The SDS is a composite of three self-rated, 10-point Likert scale response items that aim to assess the level of the subjects' impairment with regard to their work/school activities, family relationships, and social functioning. There was high internal consistency ($\alpha = 0.858$).

Procedure

This study was part of a larger study on the use of mobile applications to assess symptoms after trauma. Participants were recruited from the ED at a level 1 Trauma Center by a trained research assistant. Participants were included if they had experienced a trauma that met criterion A for a diagnosis of PTSD, which may involve actual or threatened death, physical injury, or sexual violence (American Psychiatric Association, 2013). Electronic medical records (EMR) for the patient's ED visit were reviewed by trained research assistants to determine if the individual experienced a criterion A event. Exclusion criteria included severe traumatic brain injury (TBI). Participants provided consent for inclusion in the study.

Participants completed a battery of assessments, including the PCL, and downloaded and installed a mobile application—*Metricwire* (Ontario, Canada)—on their mobile device. Every day for 30 days, participants received a notification to complete a mobile assessment of their current symptoms which included the Numeric Pain Rating Scale. Participants were called at 1-month post injury to complete assessments including the PCL, PHQ-8 and the SDS. This study's focus on pain experience and its relation to PTSD symptoms is novel and all hypotheses and statistical analyses are separate from those of the mobile assessment study. Participants were compensated for their participation.

Data Analyses

Daily reports of pain symptoms were used to generate trajectories of pain in the acute post trauma period. The pain data was extracted from *Metricwire* and organized by day after trauma. The pain scores were averaged across four-day periods to account for missing responses. For these analyses, days of 1 to 36 post trauma were selected due to the number of responses provided in this period as opposed to outside of this period.

Growth mixture modeling (GMM)—which has shown to be an effective method to determine unknown classes of trajectories in prior psychological studies (deRoon-Cassini, Mancini, Rusch, & Bonanno, 2010)—was used to identify classes of pain trajectories. Latent class growth analysis (LCGA) is a reduced version of GMM which fixes within-class variances to zero and was performed for this study (Wickrama, Lee, O'Neal, & Lorenz, 2016).

Before conducting GMM, a traditional growth curve (latent growth curve modeling or LGCM) was estimated. Unlike GMM which assumes that there are distinct latent trajectories in the sample, LGCM assumes that the same trajectory form applies to all individuals in the sample (Wickrama et al., 2016). LGCM was used to examine the overall fit of the data before examining heterogeneity within the sample. A linear growth model was specified. Goodness-of-fit was evaluated by looking at several fit statistics. Chi-square statistic is often used and is based on maximum likelihood model estimation (Wickrama et al., 2016). However, since the chi-square statistic is sensitive to sample size—small samples are not easily rejected—other statistics were also examined (Wickrama et al., 2016). These statistics included: the Bayesian, sample-size adjusted Bayesian and Aikaike information criterion (IC) indices; the root mean square error of approximation (RMSEA), the comparative fit index (CFI) and Tucker-Lewis index (TLI), and the standardized root mean residual (SRMR). An optimal fit includes lower information criteria, significant chi-square, RMSEA values close to 0.06 or below, CFI/TLI values 0.95 or greater, and SRMR value 0.08 or below (Wickrama et al., 2016).

After the homogenous linear model was examined, latent curve growth analysis (LCGA) was performed. Consistent with model recommendations, the hypothesized number of classes was tested in addition to one less and one more than expected: two class, three class and four class models were performed (Wickrama et al., 2016). In order to determine the appropriate model fit, the Bayesian, sample-size adjusted Bayesian and Aikaike information criterion (IC) indices, entropy values, the Vuong-Lo-Mendell Rubin (VLMR) Likelihood Ratio Test (LRT), the Lo-Mendell-Rubin (LMR) likelihood ratio test and the Bootstrap likelihood ratio test were examined and compared. Good model fit was associated with lower IC values, higher entropy values—above 0.80, and significant *p* values for the VLMR and LMR LRT and bootstrap LRT. The combined analysis of these fit statistics was used to determine the best model fit.

The optimal number of classes was used to evaluate differences between the classes in PTSD, depression and overall disability symptoms reported at 1-month after the traumatic injury. An ANOVA was run between pain class and 1 month and *post-hoc* analyses were examined. These analyses sought to outline the experience of pain in the acute post trauma period and to identify the role of pain in the development of other symptoms.

Results

Simple Growth Model

A simple linear growth model was estimated for pain symptoms. A linear latent growth curve model was run in *Mplus* to determine if a linear trend best characterized the pain trajectory for the entire sample. The model fit indices, shown in Table 1, suggested that the LGCM was not a good fit: χ^2(df) = 110.530 (40) $p<0.001$; RMSEA = 0.143, 90% CI (0.111 – 0.173), CFI/TLI = 0.921/0.929, SRMR = 0.119.

Classes of Pain Experience

After rejecting the linear one class model, LCGA was performed for 2 through 4 class models. Table 2 shows the fit indices for 2, 3 and 4 class models from growth mixture modeling. Initial analyses showed that LCGA models fit the data better than other GMM models, which allow for variance within the classes. The optimal model included 3-classes. The information criteria (AIC, BIC and SSABIC) for the 3-class model was higher than the 2 class but lower than the 4 class. Entropy was 0.906. The Likelihood-Ratio Tests were all statistically significant for the 3-class model with p values below 0.001.

Figure 1 shows the chosen 3-class model for pain trajectories in the first month after trauma. Each pain score represents the average pain score across 4-day intervals from days 1-36 after injury. Initial analyses showed that binning the data in these 4-day intervals showed the same overall trend as the raw scores. The first class, defined as “Decreasing”, included n = 41 (46.6%). This class was characterized by pain beginning at a moderate intercept value of 6.476 and decreasing by a slope of –0.397 per 4-day bin. The second class, defined as “High”, comprised n = 15 (17%) of the sample. This class was characterized by an intercept value of 8.215 and a linear slope of –0.029 per 4-day bin. The third group, defined as “Low” was a class of individuals (n = 32, 36.4%) whose pain started low at 3.029 and decreased at a rate of –0.300 per 4-day bin.

Table 3 shows the average latent class probabilities for the three pain classes. For the decreasing pain class, there is a 0.933 probability of membership. For the high pain class, the probability of membership is 0.962. For the low class, the probability of membership is 0.982.

Differences in symptoms of PTSD, depression and disability at 1 month

Table 4 shows that the 1-month measures of PTSD (PCL), depression (PHQ) and disability (SDS) symptoms were significantly interrelated among the whole sample. Table 5 shows the mean and standard deviations for the PCL, PHQ and SDS scores for each class and for the whole sample. One-Way ANOVA showed significant differences between groups at $p<0.01$. There was a significant difference in PCL scores among groups ($F_{2, 74} = 5.54$, p = 0.006). There was a significant difference in PHQ scores ($F_{2,73} = 5.809$, p = 0.005). There was a significant difference in SDS scores at 1-month post injury ($F_{2,73} = 7.997$, p = 0.001).

Pairwise post-hoc comparisons were then conducted to determine which groups were different from one another. Table 6 shows the results of comparing pain trajectory across the first month after trauma with PCL, PHQ and SDS scores at 1 month after injury. There were statistically significant differences in PTSD symptoms (PCL) between the low and high pain groups where the high pain group had a greater mean PTSD symptom score than the low pain group (M_{diff} = 17.365, p = 0.004). There were significant differences in PHQ scores at 1 month between the low and high pain groups showing the same trend of the higher pain group reporting higher scores (M_{diff} = 6.701, p = 0.004). The high pain class also reported significantly higher SDS scores than the low pain class at 1 month post injury (M_{diff} = 9.399, p = 0.007). SDS scores were the only metric for which the decreasing pain group showed a significant difference from the other groups. The decreasing pain class reported higher SDS scores than did those with low pain (M_{diff} = 7.626, p = 0.002). There were no significant differences in scores of the decreasing and high pain groups.

Discussion

Three distinct trajectories of pain after a traumatic injury were identified. The largest percentage of individuals (46.6%) experienced initial moderate pain that decreased over the first month after injury. The second largest group (36.4%) experienced low initial pain that decreased across the 1-month period. The third group of individuals (17%) experienced high initial pain that persisted over the first month after injury. These results are consistent with prior studies that have examined trajectories of pain experience. Sterling, Hendrikz, & Kenardy (2011) found three trajectories of pain throughout the first year after a whiplash injury. The trajectories were similar in slope and proportion to those in present findings: 45% of individuals had low initial pain, 39% of individuals had moderate pain, and 16% had consistent chronic pain. Thus, the present study provides further evidence for these three pathways of pain after a traumatic injury.

Trajectory membership was related to mental health outcomes and functional impairment at 1 month. This difference was only found between the individuals in the high and low pain class. Those in the high pain class reported significantly higher PTSD, depression and disability than did those in the low pain class. These results are consistent with prior work showing that higher pain early after a traumatic injury is associated with elevated disability and PTSD symptoms later on and that lower pain is associated with lower PTSD symptomology (Norman et al., 2008; Sawyer et al., 2015; Sterling et al., 2011). Sterling et al. (2011) examined trajectories of PTSD and neck pain in the first year after a whiplash injury. They found that 75% of individuals in the low neck pain trajectory also showed a low PTSD symptom trajectory in the first year after injury. Sawyer et al. (2015) found that none of the individuals in resolved and improving headache pain trajectories in the year following a mild traumatic brain injury had PTSD. Taken together, these studies suggest that a lower pain trajectory after a trauma may lead to improved health outcomes, including lower levels of PTSD.

Although those in the low pain trajectory showed significantly lower PTSD symptomology than those the high trajectory, the outcomes for those in the decreasing and high pain classes were not significantly different from the other groups. The decreasing pain class was only different from the low pain class in reported disability at 1 month. Those in the decreasing pain class reported significantly greater disability—in regard to work, family and recreation—than did those in the low pain class. There was no significant difference in PTSD, depression or disability at 1 month between the decreasing pain class and the high pain class. Similarly, Sawyer et al. (2015) and Sterling et al. (2011) found that that the outcomes for individuals with moderate and higher pain trajectories were less clear than for those with low pain trajectories. Individuals with a moderate pain trajectory in the first year after trauma could either develop moderate or severe PTSD symptoms (Sterling et al., 2011). Thus, additional information beyond pain is necessary to determine mental health outcomes for those in the moderate pain trajectory.

Additionally, the results of this study support the mutual maintenance model, which suggests that pain may exacerbate PTSD symptoms and PTSD may interfere with pain management (Liedl et al., 2010; Sharp & Harvey, 2001). Pain may serve as a reminder of the traumatic event, enhancing reexperiencing symptoms of PTSD, and PTSD avoidance symptoms may hinder pain management (Liedl et al., 2010; Sharp & Harvey, 2001). Therefore, higher levels of pain may serve as a reminder of the traumatic event that may exacerbate PTSD symptoms.

Clinical Implications

These results have implications for treatment after traumatic injuries. First, treating pain after a traumatic injury may both reduce pain and reduce the likelihood of developing later psychopathology. Holbrook et al. (2010) studied the effect of treating combat veterans with morphine after a trauma. Morphine has been implicated in the treatment of PTSD for both its role disrupting consolidation of traumatic memories and reducing pain. They found that morphine given after injury significantly reduced the incidence of PTSD (Holbrook et al., 2010). Therefore, pain-management strategies may also double as protective measures against the development of PTSD.

The mutual maintenance model proposes that factors exacerbating psychological distress may maintain both pain and PTSD. Reducing anxiety and pain catastrophizing symptoms early after an injury has been shown reduce later pain ratings (Kroenke et al., 2013; Scott, Kroenke, Wu, & Yu, 2016). Therefore, reducing pain may reduce PTSD symptoms and, conversely, reductions in anxiety-related symptoms may ameliorate pain symptoms after a traumatic injury.

Further research is warranted on role that integrative psychological and pharmacological early interventions to treat these conditions.

Pain trajectories may be a useful metric to inform treatment decisions after a traumatic injury. Chapman et al. (2012) suggest that different pain trajectories may inform providers about the efficacy of pain management better than taking individual pain scores. Together with the results of this study, tracking change in pain over time could inform how to effectively manage pain after trauma, and secondarily improve outcomes such as PTSD, depression and disability. The pain trajectory may be relevant to those in the decreasing and chronic pain conditions identified in this study. The long-term outcomes of those with these trajectories was less obvious than that of the low pain trajectory. Therefore, the use of pain trajectories may be an important tool in determining recovery and updating treatment of individuals after a traumatic injury.

Limitations

The present study had several limitations. Trajectories of pain experience were identified and related to psychopathology outcomes. Prior research has suggested that injury severity, traumatic brain injury (TBI), and level of consciousness may influence pain and PTSD (Delahanty, Raimonde, Spoonster, & Cullado, 2003; Melcer et al., 2014). The predictive value of injury-related factors should be studied as they may improve our understanding of how pain may lead to later outcomes. The role of pain medications was not explored. Since it has been suggested that pain management may lead to lower pain trajectories and lower PTSD symptomology, it is possible that pain medications taken in the hospital or throughout the first month may have affected the pain trajectories and subsequent PTSD outcome. Further, it would be useful to study the efficacy of in-hospital pain treatments on these trajectories as it could support the implications that early pain treatment may improve physical and mental recovery.

The sample was modest (n = 88) and consisted of a heterogeneous group of injuries. For instance, 48.6% of trauma types were motor vehicle accidents, suggesting that the results may not generalize to the physical and psychiatric outcomes of other trauma types. Having a larger data set would allow for a more comprehensive analysis of the experience of pain after a traumatic injury and how that effects recovery. Response rates to the mobile phone assessments were inconsistent such that data was aggregated across 4-day periods. It is possible that information was lost in this aggregation. Trevino et al. (2015) identified 5 trajectories of pain throughout a 4-day period after trauma, suggesting that there could be relevant variation that was not accounted for within the binned data. While preliminary analyses showed similar trends between the binned and raw data, future studies with daily pain scores may provide a more accurate account of how pain changes across the first month after trauma. Finally, pain and PTSD are likely mutually maintaining conditions and this bidirectionality was not assessed in the current study. Sterling et al. (2011) demonstrated that similar factors predict trajectories of pain and PTSD throughout the first year after trauma and that these trajectories are related to one another. Early trajectories of PTSD should be examined in the same way as pain trajectories in this study to further understand the early development of pain and PTSD after trauma.

Conclusions

The results of this study show that pain in the first month after a traumatic injury follows three trajectories which differentially relate to later PTSD, depression and disability symptoms. Having a low pain trajectory—or pain below 3 out of 10 for several days in a row—may reduce the risk of developing PTSD, while having a persistent high level of pain may relate to higher levels of PTSD symptoms. Providing early intervention that targets pain may thus prevent subsequent mental health outcomes. Further study on the early experience of pain and its effect on PTSD development is warranted.

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Table 1. *Fit indices from a linear latent growth class model (LGCM).*

Fit Indices	1 Class
Class Proportions	
AIC	1757.899
BIC	1792.582
SSABIC	1748.404
Chi-Square Test of Model Fit	110.530 (40) ***
	0.000
RMSEA	0.142
	0.111
	0.000
CFI/TLI	0.921/0.929
SRMR	0.119

Note. AIC: Aikaike Information Criteria, BIC: Bayesian Information Criteria, SSABIC: sample-size adjusted Bayesian Information Criteria; RMSEA: root mean square error of approximation; CFI/TLI: comparative fit index/Tucker-Lewis index; SRMR: standardized root mean residual

Table 2. *Fit indices for 2, 3 and 4 class latent class growth analyses (LCGA).*

Fit Indices	2 Class	3 Class	4 Class
Class Proportions	0.50233/0.49767	0.158/0.428/0.4144	0.17184/0.34693/0.16359/0.31764
AIC	2184.709	1938.343	1870.05
BIC	2219.391	1980.458	1919.596
SSABIC	2175.213	1926.813	1856.485
Entropy	0.911	0.906	0.874
VLMR LRT *p* value	0.0101	0.0085	0.2171
LMR LRT *p* value	0.0129	0.0113	0.2347
Bootstrap LRT *p* value	0.000	0.0000	0.0000

Note. AIC: Aikaike Information Criteria, BIC: Bayesian Information Criteria, SSABIC: sample-size adjusted Bayesian Information Criteria; VLMR LRT: Vuong-Lo-Mendell Rubin Likelihood Ratio Test; LMR LRT: Lo-Mendell-Rubin Likelihood Ratio Test; Bootstrap Likelihood Ratio Test

Table 3. *Average latent class probabilities for most likely latent class membership (row) by latent class (column).*

Latent Class	Most Likely Latent Class Membership		
	D	H	L
D	**0.933**	0.027	0.041
H	0.038	**0.962**	0.000
L	0.017	0.000	**0.983**

Note. D: decreasing pain trajectory; H: high pain; L: low pain

Table 4. *Standardized intercorrelations among PCL, PHQ and SDS scores.*

	PCL	PHQ	SDS
PCL	-		
PHQ	0.845***	-	
SDS	0.302**	0.454***	-

Note. *** p<0.001, **p<0.01

Table 5. *The mean and standard deviations for PCL, PHQ and SDS scores for each class of pain experience and for the whole sample.*

Class		PCL	PHQ	SDS
D	Mean	17.7850	7.9143	18.1429
(N = 41)	SD	16.47686	6.25616	9.04610
H	Mean	28.9167	11.6667	19.9167
(N = 15)	SD	18.61797	6.41494	8.51158
L	Mean	11.5517	4.9655	10.5172
(N = 32)	SD	11.87009	5.09540	8.21854
Total	Mean	17.17	7.38	15.51
	SD	16.16	6.22	9.43

Note. D: decreasing pain trajectory; H: high pain; L: low pain

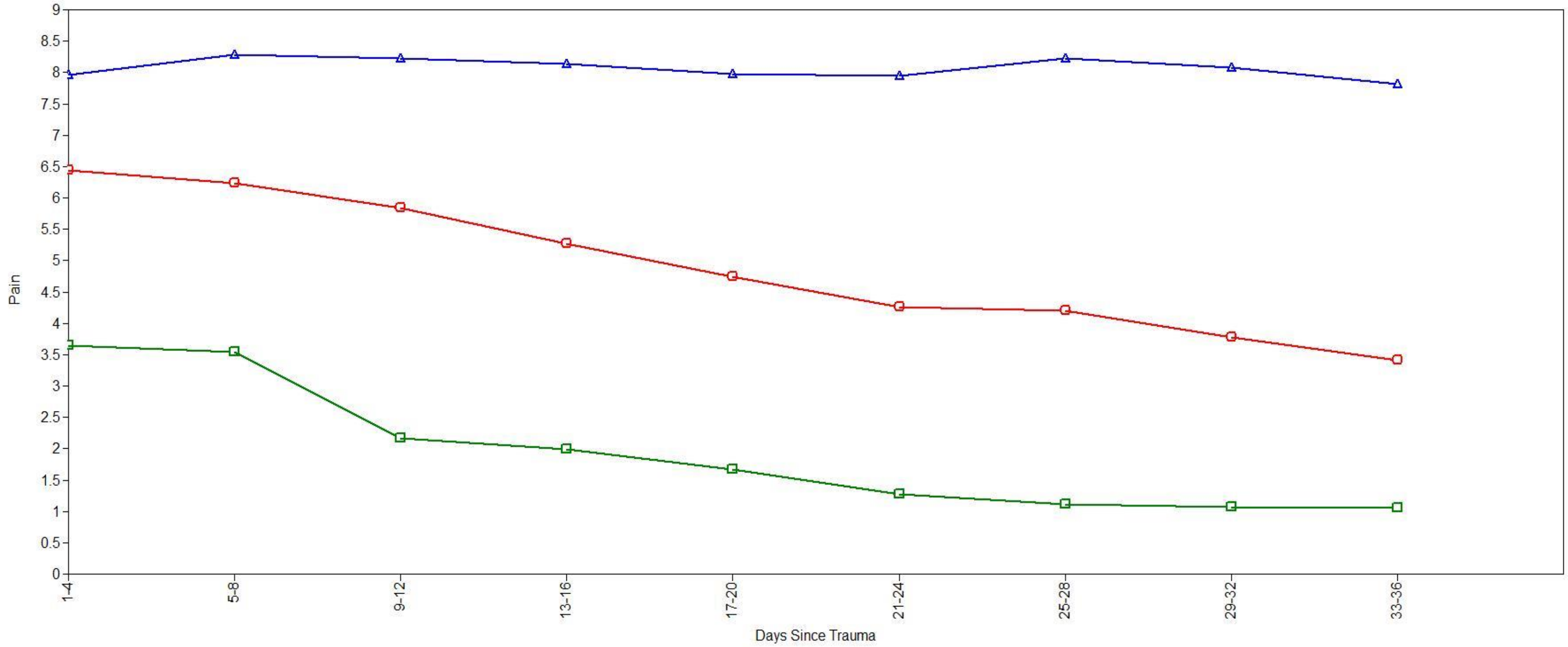
Table 6. *Results of ANOVA and post hoc comparisons of class of pain experience compared to PTSD, PHQ and disability scores at 1 month after injury.*)

Measure	(I) group	(J) group	Mean Difference (I-J)	St. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
PCL	D	H	-11.132	5.091	0.096	-23.6021	1.3389
		L	6.233	3.811	0.318	-3.1016	15.5683
	H	D	11.132	5.091	0.096	-1.3389	23.6021
		L	17.365**	5.242	0.004	4.5237	30.2062
	L	D	-6.233	3.811	0.318	-15.5683	3.1016
		H	-17.365**	5.242	0.004	-30.2062	-4.5237
PHQ	D	H	-3.752	1.962	0.179	-8.5593	1.0546
		L	2.949	1.473	0.147	-0.6595	6.5571
	H	D	3.752	1.962	0.179	-1.0546	8.5593
		L	6.701**	2.013	0.004	1.7689	11.6334
	L	D	-2.949	1.473	0.147	-6.5571	0.6595
		H	-6.701**	2.013	0.004	-11.6334	-1.7689
SDS	D	H	-1.774	2.899	1	-8.8698	5.3221
		L	7.626**	2.174	0.002	2.2991	12.9521
	H	D	1.774	2.896	1	-5.3221	8.8698
		L	9.399**	2.971	0.007	2.1185	16.6804
	L	D	-7.626**	2.174	0.002	-12.9521	-2.2991

	H	-9.399**	2.971	0.007	-16.6804	-2.1185

Note. D: decreasing pain trajectory; H: high pain; L: low pain. ** p<0.01

Figure 1. *Three-class model of pain trajectories across the first month after trauma.*



Note. Blue: high pain trajectory (N = 15, 17%); Red: decreasing pain (N = 41, 46.6%); Green: low pain (N = 32, 36.4%)