

Pain after a motor vehicle crash: The role of socio-demographics, crash characteristics and peri-traumatic stress symptoms

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Abstract

Background: The vast majority of individuals who come to the emergency department (ED) for care after a motor vehicle collision (MVC) are diagnosed with musculoskeletal strain only and are discharged to home. A significant subset of this population will still develop persistent pain and posttraumatic psychological sequelae may play an important role in pain persistence.

Methods: We conducted a multisite longitudinal cohort study of adverse post-traumatic neuropsychiatric sequelae among patients seeking ED treatment in the aftermath of a traumatic life experience. We report on a sub-group of patients ($n = 666$) presenting after an MVC, the most common type of trauma and we examine associations of socio-demographic and MVC characteristics, and persistent pain 8 weeks after MVC. We also examine the degree to which these associations are related to peritraumatic psychological symptoms and 2-week acute stress reactions using an applied approach.

Results: Eight-week prevalence of persistent moderate or severe pain was high (67.4%) and positively associated with patient sex (female), older age, low socioeconomic status (education and income) and pain severity in the ED. Peritraumatic stress symptoms (distress and dissociation) appear to exert some influence on both acute pain and the transition from acute to persistent pain.

Discussion and Conclusions: The early aftermath of an MVC may be an important time period for intervening to prevent and reduce persistent pain. Substantial variation in mediating pathways across predictors also suggests potential diverse and complex underlying biological and psychological pathogenic processes are at work in the early weeks following trauma.

Significance: The first several days after trauma may dictate recovery trajectories. Persistent pain, pain lasting beyond the expected time of recovery, is associated with pain early in the recovery period, but also mediated through other pathways. Future work is needed to understand the complex neurobiological processes involved in the development of persistent and acute post-traumatic pain.

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1 | INTRODUCTION

A substantial subset of individuals experiencing traumatic stress develop persistent adverse post-traumatic neuropsychiatric sequelae (APNS) (Koenen et al., 2017; Santiago et al., 2013). APNS include post-traumatic stress, post-concussive (somatic) symptoms, depressive symptoms and chronic pain (Kessler, 2000; Kessler et al., 1995; Roberts et al., 2011). As with the other types of APNS, the prevention of persistent and chronic pain after traumatic stress exposure is an important public health priority: Chronic pain afflicts more than 30% of US adults, (Grol-Prokopczyk, 2017; Johannes et al., 2010; McBeth & Jones, 2007) accounts for more than \$260 billion in annual US health care costs, (Gaskin & Richard, 2012) and drives the majority of US opioid prescriptions (Ernst et al., 2015; Moshfegh et al., 2018).

Hundreds of millions of opportunities occur each year to screen and initiate interventions to prevent APNS, including chronic pain, however screening and intervention are rarely performed. For example, very few of the 40 million Americans who present to an emergency department (ED) each year in the immediate aftermath of trauma exposure receive any screening or interventions for APNS (Roberts et al., 2011). Efforts to develop such interventions are hampered by critical knowledge gaps, including knowledge gaps related to the pathogenesis of specific APNS such as chronic pain.

Motor vehicle collisions (MVCs) in particular are one of the most common life-threatening traumatic stress exposures and even minor MVCs can result in high morbidity from chronic pain and other APNS (Ravn et al., 2019, 2020). In the US there are over 4 million ED visits related to MVCs each year (Albert & McCaig, 2015). More than 90% of individuals who come to the ED for care after MVC are discharged home with a diagnosis of musculoskeletal strain only, (Bortsov et al., 2013). However, a substantial portion of this population develops persistent pain, that is pain that lasts beyond the expected time of normal healing (Hartling et al., 2001; McLean et al., 2014; Suissa et al., 2001) and ultimately persistent pain can become chronic (Nolet et al., 2020). Historically such pain was attributed to tissue injury, but more recently neurobiological stress systems have been implicated in both posttraumatic psychologic symptoms and pain persistence after physical trauma (McLean, 2016). Furthermore, the development of post-traumatic stress disorder and chronic pain are often co-morbid, suggesting potentially a shared neurobiological mechanism (Ravn et al., 2020). Targeting acute peritraumatic stress after trauma has also been shown to improve pain outcomes (Sterling et al., 2019) and other APNS (Gil-Jardine et al., 2018). Peritraumatic stress can be thought of as the acute psychological response to trauma and is often characterized by specific clusters of symptoms, particularly, distress and dissociation. Since the presence of peritraumatic stress symptoms (distress and dissociation) predict PTSD

independent of trauma severity or sociodemographic characteristics, (Bryant, 2011) it reasons that peritraumatic distress and dissociation may also mediate pain persistence after a traumatic event. This is particularly important to understand as the early aftermath of trauma exposure may be the an optimal time for therapeutic intervention (Bryant, 2003).

In this analysis, we examine the association of known PTSD predictors (e.g. sex, race/ethnicity, MVC-related characteristics and peritraumatic stress symptoms, [Bryant, 2011]) with both acute and persistent pain development after an MVC. In addition, we explored whether associations between socio-demographic, MVC-related, or peritraumatic stress symptoms and persistent pain were due to their role in acute pain, rather than exerting influence on the transition from acute to persistent pain. We investigate these important issues of APNS dynamics in a large prospective cohort of ED patients involved in an MVC.

2 | METHODS

2.1 | Overview

Progress in improving our ability to help prevent and treat APNS is being conducted through programmatic research; the National Institute of Mental Health recently initiated a collaborative study known as the AURORA (Advancing Understanding of Recovery after trauma) study designed to collect a combination of prospective genomic, neuroimaging, psychophysical, physiological, neurocognitive, digital phenotype and self-report data from an enriched sample of approximately 5,000 trauma survivors recruited from EDs in the early aftermath of trauma and to follow these patients closely for 1 year after trauma exposure. As described in more detail elsewhere (McLean et al., 2020), each of the four traditional APNS (post-traumatic stress, post-concussion syndrome, depression and pain) and their intermediate phenotypes are being characterized in AURORA with both self-reported scales and biomarkers from different Research Domain Criteria (RDoC) 'units of analysis' (<https://bit.ly/2pudCZH>) to assess data-driven multidimensional phenotypes based on the most frequent symptoms observed among trauma survivors. With supplemental support (see Acknowledgements), AURORA aims to produce a well-powered, multi-layered publicly available dataset capable of identifying APNS and studying risk and protective factors for APNS onset and course.

Initial AURORA analyses are focusing on patterns and associations of trauma experiences and peritraumatic symptoms with the separate traditional APNS in the first 8 weeks after trauma exposure. This timeframe was chosen as the early aftermath of trauma exposure is likely a critical intervention period and because pain trajectories are relatively stable 8 weeks after trauma (Hu et al., 2016; Sterling et al., 2011;

Ulirsch, Weaver, et al., 2014). In this empirical report of AURORA findings, we focus on the development of persistent moderate to severe pain among participants involved in a MVC. We consider only the AURORA respondents who were drivers or passengers involved in an MVC, as this is by far the most common trauma encountered in EDs and makes up the vast majority of initial AURORA participants. We further consider the associations of socio-demographic and MVC characteristics with moderate/severe pain (MSP) as of the 8-week post-MVC assessment and the extent to which these associations are mediated through peritraumatic distress and dissociation (assessed in the immediate aftermath of the MVC in the participating EDs) and MSP measured at the 2-week post-MVC assessment.

2.2 | Participants

AURORA enrolment began in September 2017. This analysis includes participants who completed the 8-week assessment (described below) enrolled through March 2019. Enrolment occurred at 23 urban EDs across the US. To qualify for participation, patients had to present to a study ED within 72 hr of exposure to a qualifying trauma (physical or sexual

assault, MVC, other life-threatening traumatic events). As noted in the introduction, this investigation focuses on patients who were occupants of a vehicle involved in a MVC. In addition to having a MVC, AURORA participants were required to be 18- to 75-years-old, able to speak and read English, able to provide informed consent and to follow protocol at the time of enrolment, physically able to use a smart phone (i.e. not deaf, blind, or have physical impairment that prevented their use of one) (Figure 1). We excluded patients who had a solid organ injury American Association for the Surgery of Trauma (AAST) Grade >1, significant haemorrhage, required an operative intervention, or were likely to be admitted for >72 hr. Of the 867 patients enrolled at baseline, 666 were involved in an MVC trauma and completed both the 2- and 8-week assessments and were analysed as part of this investigation. A comparison of all those enrolled versus those included in the final analyses are presented in the appendix (Table A3).

2.3 | Measures

After providing written informed consent in the ED, each participant received an interviewer-administered assessment

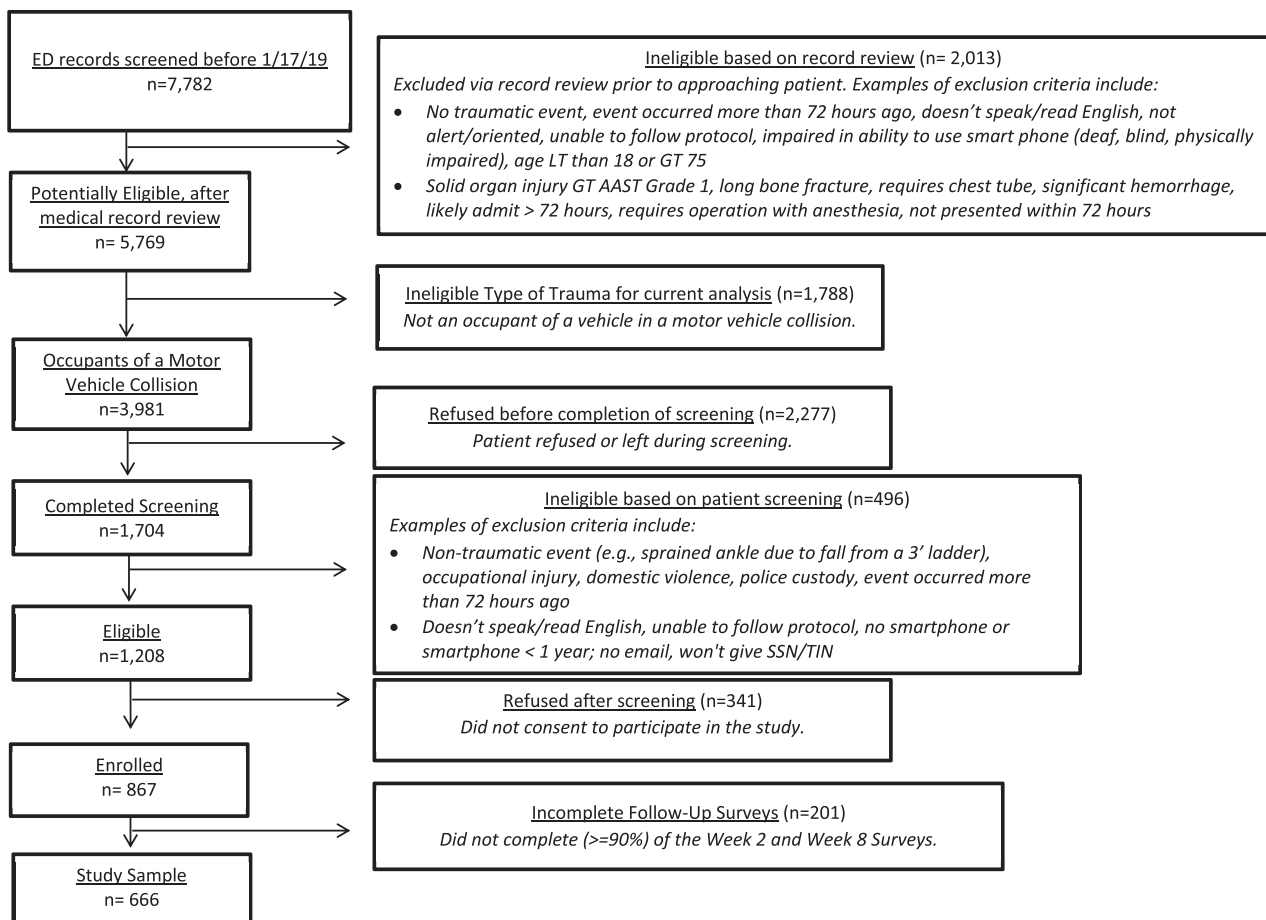


FIGURE 1 Flowchart of patients reviewed in records at the participating EDs as of 1/17/19

that included both self-report questions and biological sample collections described elsewhere (McLean et al., 2020). The self-report questions assessed characteristics of the trauma and peritraumatic symptoms described below. Subsequent 2- and 8-week web surveys were then sent by text or e-mail for self-completion but could be completed with the help of telephone interviewers when this was preferred by the participant. Each participant was reimbursed \$60 for the ED assessment, \$40 for the 2-week survey, and \$40 for the 8-week survey. These procedures were approved on May 12, 2017 by the Biomedical IRB at UNC Chapel Hill through the Office of Human Research Ethics, which also served as the central IRB for all enrolling ED sites.

Baseline surveys collected in the ED assessed socio-demographics, MVC characteristics, and injury information. Socio-demographics included age (18–24, 25–34, 35–49, 50–75), sex, race-ethnicity (Non-Hispanic Black, Non-Hispanic White, Hispanic, Other), marital status (married/cohabitating, previously married, never married), education (less than high school graduate, high school graduate, some college, college graduate), family income before taxes (divided into approximate tertiles of less than \$19K, \$19–35K, more than \$35K), and employment status (employed vs. others). A number of MVC and injury characteristics that were recorded and considered here include: whether the patient was the driver (with vs. without passengers) or passenger; whether the collision was with a moving vehicle or stationary object; the amount of damage to the patient's vehicle (on a scale from 'none' to 'severe'); severity of injuries sustained by people other than the patient (separately for passengers in the patient's vehicle and others); transported to the ED by ambulance or some other mode (immediately or delayed); patient injuries (hit head, sustained a traumatic brain injury, defined as experiencing a head injury with either loss of consciousness, amnesia or disorientation (McLean et al., 2009); severity of injury as based on the Abbreviated Injury Scale (AIS; [Loftis et al., 2018]); admitted vs. discharged without an admission), and patient ratings in the ED of current pain and other symptoms compared to during the 30 days before the MVC.

Overall pain severity was assessed in the ED with a single question using a 0–10 response scale for each of the two time periods (i.e. currently and 30 days before the MVC), where 0 means 'no pain or tenderness' and 10 means 'severe pain or tenderness' (Farrar et al., 2001). The difference in participant-reported overall pain severity between these two time points was transformed into an overall pain severity score was then standardized to a within-sample mean of 0 and variance of 1. Comparable pairs of questions were asked about the severity of 20 other somatic symptoms at the same time periods by asking 'how much of a problem' each symptom was on a 0–10 scale where 0 means 'no problem' and 10 means 'a major problem'. The 20 symptoms included 12 adapted from the

Pennebaker Inventory of Limbic Languidness scale (PILL; [Pennebaker & Watson, 1991]) and an additional 8 from the Rivermead Post-Concussion Symptoms Questionnaire (RPQ; [King et al., 1995]). Each individual-level difference score was standardized to a mean of 0 and a variance of 1. These 20 standardized difference scores were then summed into an overall scale (Cronbach's $\alpha=0.85$).

Peritraumatic stress symptoms, distress and dissociation, were assessed in the ED with a rationally-selected 8 items from the short form of the 13-item Peritraumatic Distress Inventory (PDI; [Brunet et al., 2001]) and the 5-item revised Michigan Critical Events Perception Scale (MCEPS; [Michaels et al., 1999]), both validated in MVC patients. The 8 PDI items were selected using part-whole correlation ($r = .946$) derived from data in an existing cohort of MVC patients ($n = 1861$) (Beaudoin et al., 2018). We modified the introduction to both question series to ask about frequency of feelings and experiences 'during and immediately after' the MVC and used a 0–4 response scale for the PDI and a 1–5 response scale for the MCEPS ('none of the time', 'a little', 'some', 'most', 'all or almost all the time'). Scores were summed to create scales with these respective ranges, 0–32 for PDI and 5–25 for MCEPS scales. Cronbach's α was 0.80 for the PDI and 0.77 for the MCEPS. Each score was subsequently standardized to a mean of 0 and variance of 1 to facilitate interpretation of associations with later MSP.

Pain outcomes were evaluated using both dichotomous and continuous measures at 2 and 8 weeks after the traumatic event in order to reflect ongoing acute and persistent pain, respectively. These time frames were chosen as the early post-traumatic period is of interest in terms of intervention strategies and by 8 weeks pain trajectories are relatively well established, meaning the likelihood of additional recovery is low (Hu et al., 2016; Sterling et al., 2011; Ulirsch, Weaver, et al., 2014). In the week 2 and week 8 surveys, pain was assessed using a Pain Intensity Numeric Rating Scale (PI-NRS), a single-item measure of pain intensity (Farrar et al., 2001). Patients were asked to report the 'usual intensity' of any and all physical pain in the past 2 weeks (2-week survey) or past 30 days (8-week survey) on a 0–10 scale, where 0 = 'no pain' and 10 = 'the worst possible pain'. A score of 4 or more on this single item was used as the threshold to define MSP. For our continuous scale, we used a count of the number of body regions with clinically significant new or worsening pain, which compared 18 body region pain severity scores at 30 days before the MVC to the past 2 weeks (2-week survey) or past 30 days (8-week survey). Clinically significant new or worsening pain was defined as an increase in pain severity by 2 or more points (on a 0–10 response scale) from pre-trauma to post-trauma (Ulirsch, Ballina, et al., 2014). Cronbach's α was 0.91 for 2-week clinically significant new or worsening pain and 0.95 for 8-week clinically significant new or worsening pain (Bortsov et al., 2013, 2014; McLean et al., 2014).

2.4 | Analysis methods

We first examined bivariate associations between peritraumatic symptom scales and 2- and 8-week MSP outcomes. We also constructed logistic regression equations to estimate the separate, joint, and interactive associations between peritraumatic symptom scales and 8-week MSP. We examined whether or not the association of peritraumatic symptoms (distress and dissociation) on 8-week MSP was mediated by 2-week pain in a model adjusting for 2-week MSP (both the dichotomous yes/no MSP variable and continuous clinically significant new or worsening pain symptom scores). The sample size led us not to carry out a formal mediation analysis (Pan et al., 2018), but rather we explore possible mediating effects through determining associations (odds-ratios) with the 8-week outcome with and without controls for the peritraumatic symptoms and the 2-week outcomes. Future analyses of the larger AURORA sample will use more formal decomposition methods if we find evidence of important mediating processes based on preliminary analyses such as those reported here.

Linear regression models were then estimated for the associations of socio-demographic and MVC characteristics with peritraumatic distress and dissociation, followed by expanded logistic models for the associations of these same predictors with 8-week MSP. Estimates were generated for models both with and without controls for peritraumatic symptoms and 2-week MSP, which allowed us to examine the extent to which the gross associations of the predictors with 8-week MSP were mediated by peritraumatic symptoms and 2-week MSP. Logits and logits ± 2 standard errors were exponentiated and are reported as odds-ratios (ORs) with 95% confidence intervals (CIs). Statistical significance was evaluated using $\alpha=0.05$ -level two-sided tests.

2.5 | Missing data

Given the small amount of item-level missing data (<1% for any item, range of 0–5 missing responses per item) item missing values were imputed using simple mean/modal/median imputations. Data were assumed to be missing at random. Complete information was collected on patient age, sex, MVC characteristics and most patient injury characteristics. The exception was that definitive information on whether the patient experienced a head injury was missing for 8.6% of patients and the presence of missingness was not associated with socio-demographics characteristics. Small numbers of patients were also missing ED information on pain severity (2 patients) and severity of other somatic symptoms 30-days before the MVC (1–2 items for 34 patients, all 20 items for 2 patients). Central tendency imputations were then used for the small amount of missing data on peritraumatic symptoms (mean imputation),

education and income (median imputation), and race/ethnicity, marital status and employment status data (mode imputation). MSP for the small number of patients missing on the single overall pain item ($n = 2$ 2-week and $n = 4$ 8-week) were assigned using modal item-level imputations. More respondents were missing 1 or more of the 2-week continuous clinically significant new or worsening pain difference scores ($n = 26$), and 8-week continuous score ($n = 29$). Missing items were imputed to the mode of the missing item(s) to calculate the pain difference scores for each body region.

3 | RESULTS

3.1 | Prevalence of moderate to severe overall pain (MSP) in the aftermath of MVC

The overall prevalence (standard error, n) of MSP 2 and 8 weeks after MVC in the September 2017 – March 2019 AURORA MVC sample was 81.4% (1.5, $n = 542$) and 67.4% (1.8, $n = 449$), respectively. Among participants who reported moderate to severe pain at 2 weeks, 77.1% (1.8, $n = 418$) continued to have MSP at 8 weeks. A smaller but still sizeable proportion of participants who did not have MSP at 2 weeks, 25.0% (3.9, $n = 31$, reported MSP at 8-weeks, representing 6.9% of all 8-week participants.

3.2 | Associations of socio-demographics, MVC, and injury characteristics with peritraumatic symptoms

Table 1 displays the socio-demographic characteristics of the study participants. A majority of participants were younger than age 35, women, Non-Hispanic Black, had completed at some education after high school, and were employed. Table 2 displays MVC and injury characteristics. Most participants had minor injuries such as isolated musculoskeletal strains or abrasions/contusions (AIS-Max = 1) and were discharged home (>95%) after ED evaluation. Peritraumatic distress was significantly elevated among females ($\beta = 0.5$), those with the lowest family incomes ($\beta = 0.2$), and those not employed ($\beta = 0.2$) (Table A1). A multivariate model with all socio-demographic characteristics significantly predicted distress ($F_{15,650} = 3.0$, $p < .001$) but not dissociation ($F_{15,650} = 0.7$, $p = .80$), a relationship explored in detail in a companion publication. The individual's role in the MVC (i.e. passenger vs. driver), whether anyone other than in the patient's vehicle was injured, and two indicators of patient injury (AIS-Max score, admitted vs. discharged) were unrelated to peritraumatic distress or dissociation. However, both were significantly and positively associated with the amount of damage sustained by the patient's vehicle ($\beta = 0.6$ – 0.4 for

TABLE 1 Distributions and univariate associations between socio-demographic characteristics and self-reported pain with and without controls for peritraumatic distress and dissociation in the Freeze 1 AURORA MVC sample ($n = 666$)

| | 8-week | | | | 2-week | | | | 8-week controlling 2-week | | | |
|---------------------------------|----------------------|------------|----------------------|------------|----------------------|------------|----------------------|------------|---------------------------|------------|----------------------|------------|
| | Model 3 ^a | | Model 4 ^b | | Model 1 ^a | | Model 2 ^b | | Model 5 ^c | | Model 6 ^d | |
| | OR | (95% CI) | OR | (95% CI) | OR | (95% CI) | OR | (95% CI) | OR | (95% CI) | OR | (95% CI) |
| Age | | | | | | | | | | | | |
| 50+ | 2.6* | (1.5, 4.5) | 2.7* | (1.5, 4.6) | 1.5 | (0.8, 2.8) | 1.5 | (0.8, 2.9) | 2.8* | (1.5, 5.1) | 2.8* | (1.5, 5.2) |
| 35–49 | 1.9* | (1.2, 3.0) | 1.9* | (1.2, 3.1) | 1.5 | (0.9, 2.6) | 1.6 | (0.9, 2.7) | 1.8* | (1.1, 3.1) | 1.9* | (1.1, 3.1) |
| 25–34 | 1.2 | (0.8, 1.8) | 1.2 | (0.8, 1.9) | 1.2 | (0.7, 2.1) | 1.3 | (0.8, 2.2) | 1.1 | (0.7, 1.8) | 1.2 | (0.7, 1.9) |
| 18–24 | Ref | – | Ref | – | Ref | – | Ref | – | Ref | – | Ref | – |
| χ^2_3 * | 17.1* | | 16.7* | | 2.8 | | 3.1 | | 14.7* | | 14.3* | |
| Sex (female) | 1.8* | (1.2, 2.5) | 1.6* | (1.1, 2.3) | 2.2* | (1.5, 3.4) | 2.2* | (1.4, 3.4) | 1.4 | (0.9, 2.1) | 1.2 | (0.8, 1.9) |
| Race/ethnicity | | | | | | | | | | | | |
| Non-Hispanic Black | 1.1 | (0.8, 1.6) | 1.1 | (0.8, 1.6) | 0.8 | (0.5, 1.3) | 0.8 | (0.5, 1.3) | 1.1 | (0.7, 1.7) | 1.2 | (0.8, 1.7) |
| Non-Hispanic White | Ref | – | Ref | – | Ref | – | Ref | – | Ref | – | Ref | – |
| Hispanic | 1.4 | (0.8, 2.5) | 1.4 | (0.7, 2.5) | 0.9 | (0.4, 1.8) | 0.8 | (0.4, 1.7) | 1.4 | (0.7, 2.8) | 1.4 | (0.7, 2.9) |
| Other | 0.7 | (0.3, 1.7) | 0.7 | (0.3, 1.8) | 0.4 | (0.1, 1.1) | 0.4 | (0.1, 1.0) | 0.9 | (0.3, 2.7) | 1.0 | (0.3, 2.9) |
| χ^2_3 * | 2.1 | | 2.0 | | 3.4 | | 3.6 | | 1.2 | | 1.3 | |
| Marital status | | | | | | | | | | | | |
| Married/ cohabitating | Ref | – | Ref | – | Ref | – | Ref | – | Ref | – | Ref | – |
| Previously married ^e | 1.2 | (0.7, 2.0) | 1.1 | (0.7, 1.9) | 0.9 | (0.5, 1.6) | 0.8 | (0.5, 1.6) | 1.3 | (0.7, 2.4) | 1.3 | (0.7, 2.3) |
| Never married | 0.8 | (0.6, 1.2) | 0.8 | (0.6, 1.2) | 0.7 | (0.5, 1.1) | 0.7 | (0.5, 1.1) | 0.9 | (0.6, 1.3) | 0.9 | (0.6, 1.3) |
| χ^2_2 * | 2.3 | | 2.0 | | 2.2 | | 2.1 | | 2.1 | | 1.7 | |
| Education | | | | | | | | | | | | |
| College graduate | Ref | – | Ref | – | Ref | – | Ref | – | Ref | – | Ref | – |
| Some college | 1.2 | (0.8, 1.9) | 1.2 | (0.8, 1.8) | 1.0 | (0.6, 1.8) | 1.0 | (0.6, 1.7) | 1.2 | (0.8, 2.0) | 1.2 | (0.7, 1.9) |
| High school graduate | 0.9 | (0.5, 1.4) | 0.8 | (0.5, 1.4) | 0.7 | (0.4, 1.3) | 0.7 | (0.4, 1.3) | 1.0 | (0.6, 1.7) | 1.0 | (0.6, 1.6) |
| Less than high school | 2.2* | (1.1, 4.5) | 2.1* | (1.0, 4.2) | 1.0 | (0.5, 2.1) | 0.9 | (0.4, 1.9) | 2.6* | (1.2, 5.6) | 2.4* | (1.1, 5.2) |
| χ^2_3 * | 8.5* | | 7.0 | | 2.1 | | 1.8 | | 6.6 | | 5.7 | |
| Income^f | | | | | | | | | | | | |
| More than \$35K | Ref | – | Ref | – | Ref | – | Ref | – | Ref | – | Ref | – |
| \$19–35K | 1.3 | (0.9, 1.9) | 1.2 | (0.8, 1.7) | 1.6 | (1.0, 2.6) | 1.5 | (0.9, 2.4) | 1.1 | (0.7, 1.7) | 1.0 | (0.7, 1.6) |
| Less than \$19K | 1.5* | (1.0, 2.2) | 1.4 | (1.0, 2.1) | 1.3 | (0.8, 2.1) | 1.2 | (0.8, 2.0) | 1.4 | (0.9, 2.2) | 1.4 | (0.9, 2.1) |
| χ^2_2 * | 4.3 | | 3.0 | | 3.6 | | 2.3 | | 2.5 | | 2.1 | |
| Employed (yes vs. no) | 0.7 | (0.4, 1.0) | 0.7 | (0.5, 1.1) | 0.8 | (0.5, 1.3) | 0.8 | (0.5, 1.4) | 0.7 | (0.5, 1.1) | 0.8 | (0.5, 1.2) |

Abbreviations: CI, confidence interval; MVC, motor vehicle collision; OR, odds ratio.

^aWithout controls for peritraumatic distress/dissociation.

^bWith controls for peritraumatic distress/dissociation.

^cWith controls for 2-week pain (both continuous and categorical) but not peritraumatic distress/dissociation.

^dWith controls for 2-week pain (both continuous and categorical) and peritraumatic distress/dissociation.

^eSeparated, widowed, or divorce.

^fFamily income before taxes.

*Significant at the 0.05 level, two-sided test.

TABLE 2 Distributions and net univariate associations of MVC and injury characteristics after controlling socio-demographics with self-reported pain with and without controls for peritraumatic distress and dissociation in the Freeze 1 A

| | 8-week | | | | 2-week | | | | 8-week controlling 2-week | | | |
|--|----------------------|-------------|----------------------|------------|----------------------|------------|----------------------|------------|---------------------------|------------|----------------------|------------|
| | Model 3 ^a | | Model 4 ^b | | Model 1 ^a | | Model 2 ^b | | Model 5 ^c | | Model 6 ^d | |
| | OR | (95% CI) | OR | (95% CI) | OR | (95% CI) | OR | (95% CI) | OR | (95% CI) | OR | (95% CI) |
| Role in MVC | | | | | | | | | | | | |
| Passenger | 1.0 | (0.6, 1.5) | 1.0 | (0.6, 1.5) | 1.2 | (0.7, 2.0) | 1.2 | (0.7, 2.1) | 0.9 | (0.6, 1.4) | 0.9 | (0.6, 1.5) |
| Driver with others | 1.1 | (0.7, 1.7) | 1.0 | (0.6, 1.6) | 0.8 | (0.5, 1.4) | 0.8 | (0.4, 1.3) | 1.2 | (0.7, 2.0) | 1.1 | (0.7, 1.9) |
| Driver alone | Ref | – | Ref | – | Ref | – | Ref | – | Ref | – | Ref | – |
| $\chi^2_2^*$ | 0.2 | | 0.0 | | 1.3 | | 1.8 | | 0.8 | | 0.5 | |
| Your vehicle collided with | | | | | | | | | | | | |
| Other moving vehicle | 0.9 | (0.5, 1.4) | 0.8 | (0.5, 1.3) | 0.6 | (0.3, 1.1) | 0.5 | (0.3, 1.0) | 1.0 | (0.6, 1.8) | 1.0 | (0.6, 1.7) |
| Stationary object | 0.7 | (0.4, 1.3) | 0.6 | (0.3, 1.2) | 0.5 | (0.2, 1.1) | 0.5 | (0.2, 1.1) | 0.8 | (0.4, 1.6) | 0.8 | (0.4, 1.5) |
| Other ^e | Ref | – | Ref | – | Ref | – | Ref | – | Ref | – | Ref | – |
| $\chi^2_2^*$ | 1.6 | | 1.9 | | 3.5 | | 4.0 | | 0.8 | | 0.8 | |
| Damage to your vehicle | | | | | | | | | | | | |
| Severe | 1.9 | (0.9, 3.7) | 1.5 | (0.7, 3.0) | 1.4 | (0.7, 3.2) | 1.2 | (0.5, 2.7) | 1.8 | (0.8, 3.8) | 1.5 | (0.7, 3.2) |
| Moderate | 1.2 | (0.6, 2.5) | 1.1 | (0.5, 2.4) | 1.0 | (0.4, 2.2) | 1.0 | (0.4, 2.2) | 1.3 | (0.6, 2.9) | 1.3 | (0.6, 2.8) |
| Minor | 1.9 | (0.8, 4.6) | 2.0 | (0.8, 4.8) | 2.3 | (0.8, 6.9) | 2.6 | (0.9, 8.0) | 1.5 | (0.6, 3.9) | 1.6 | (0.6, 4.0) |
| Other ^f | Ref | – | Ref | – | Ref | – | Ref | – | Ref | – | Ref | – |
| $\chi^2_3^*$ | 6.7 | | 3.9 | | 5.5 | | 5.0 | | 3.1 | | 1.5 | |
| Passengers with injuries (0–4 standardized)^g | | | | | | | | | | | | |
| Others with injuries (any vs. none) ^g | 0.9 | (0.5, 1.5) | 0.8 | (0.5, 1.4) | 1.7 | (0.8, 3.6) | 1.5 | (0.7, 3.3) | 0.6 | (0.4, 1.2) | 0.6 | (0.3, 1.1) |
| Transportation to ED | | | | | | | | | | | | |
| Ambulance | 1.2 | (0.8, 1.8) | 1.1 | (0.7, 1.6) | 1.5 | (0.9, 2.3) | 1.2 | (0.8, 2.0) | 1.0 | (0.7, 1.6) | 0.9 | (0.6, 1.5) |
| Other immediately | 0.6 | (0.4, 1.1) | 0.6 | (0.4, 1.1) | 0.8 | (0.4, 1.5) | 0.8 | (0.4, 1.4) | 0.6 | (0.3, 1.0) | 0.6 | (0.3, 1.0) |
| Other delay | Ref | – | Ref | – | Ref | – | Ref | – | Ref | – | Ref | – |
| $\chi^2_2^*$ | 7.3* | | 4.9 | | 5.2 | | 3.0 | | 5.1 | | 4.2 | |
| Personal injury | | | | | | | | | | | | |
| Hit head (yes vs. no) | 1.2 | (0.9, 1.7) | 1.1 | (0.8, 1.5) | 1.1 | (0.7, 1.6) | 0.9 | (0.6, 1.4) | 1.1 | (0.8, 1.7) | 1.1 | (0.7, 1.6) |
| TBI (yes vs. no) | 1.0 | (0.7, 1.4) | 0.7 | (0.5, 1.1) | 1.1 | (0.7, 1.7) | 0.8 | (0.5, 1.2) | 0.9 | (0.6, 1.3) | 0.7 | (0.5, 1.1) |
| AIS-Max ^h (2+ vs. 1) | 1.4 | (0.8, 2.4) | 1.4 | (0.8, 2.3) | 1.8 | (0.9, 3.6) | 1.7 | (0.8, 3.3) | 1.3 | (0.7, 2.3) | 1.2 | (0.7, 2.2) |
| Admitted (yes vs. no) | 0.7 | (0.3, 1.7) | 0.6 | (0.3, 1.5) | 0.7 | (0.3, 1.7) | 0.6 | (0.2, 1.4) | 0.7 | (0.3, 1.9) | 0.7 | (0.3, 1.8) |
| Severity of pain ⁱ | 1.5* | (1.3, 10.8) | 1.4* | (1.2, 1.7) | 1.8* | (1.4, 2.2) | 1.7* | (1.4, 2.1) | 1.3* | (1.0, 1.5) | 1.2 | (1.0, 1.5) |
| Severity of other somatic symptom ^j | 1.2 | (1.0, 1.4) | 1.1 | (0.9, 1.3) | 1.3* | (1.0, 1.6) | 1.2 | (1.0, 1.5) | 1.0 | (0.8, 1.2) | 1.0 | (0.8, 1.2) |

Abbreviations: AIS, Abbreviated Injury Scale; CI, confidence interval; ED, emergency department; MVC, motor vehicle collision; OR, odds ratio; TBI, traumatic brain injury.

^aWithout controls for peritraumatic distress/dissociation.

^bWith controls for peritraumatic distress/dissociation.

^cWith controls for 2-week pain (both continuous and categorical) but not peritraumatic distress/dissociation.

^dWith controls for 2-week pain (both continuous and categorical) and peritraumatic distress/dissociation.

^eNo collision ($n = 81$), “other” ($n = 8$), and “don't know” ($n = 8$).

^fNone ($n = 12$) and “don't know” ($n = 31$).

^gModerate or severe injuries.

^hMax score of the nine AIS regions.

ⁱSelf-reported 0–10 scale on pain intensity right now, standardized to mean = 0 and standard deviation = 1.

^jSum of all differences in each somatic symptom between 30-day (self-reported 0–10 scale) and right now (self-reported 0–10 scale), standardized to mean = 0 and standard deviation = 1.

*Significant at the 0.05 level, two-sided test.

severe vs. no vehicle damage), the number of passengers with moderate-severe injuries in the vehicle ($\beta = 0.1$), and transport to the ED by ambulance ($b = 0.4\text{--}0.3$). Peritraumatic distress and dissociation were both positively associated with self-reported severity of pain ($\beta = 0.2\text{--}0.1$) and other somatic symptoms ($\beta = 0.2$) (Table A2).

3.3 | Associations of socio-demographics, MVC, and injury characteristics with 2- and 8-week moderate to severe pain

Women were significantly more likely than men to report MSP in the 2 weeks after the MVC not only in the crude model (OR = 2.2) but also after adjusting for peritraumatic symptoms (OR = 2.2) (Table 1). This means that women were significantly more likely than men with the same peritraumatic symptoms to develop MSP early in the course of trauma recovery. The gross odds of having MSP at 8 weeks (Table 3, M3) was significantly elevated among individuals in the two highest age categories (OR 1.9–2.6), women (OR = 1.8), individuals with less than a high school education (OR = 2.2), and individuals in the lowest income categories (OR = 1.5). Income was no longer significant when peri-traumatic distress and dissociation were controlled for (Table 3, M4). Notably, there was no significant sex difference in 8-week MSP once 2-week pain symptoms were controlled for (OR = 1.2–1.4), indicating that MSP persistence was not higher among women than men who had the same pain at 2 weeks. In contrast, after controlling for peritraumatic distress and dissociation, as well as 2-week MSP, patients in the two highest age categories (ages 35–49, 55+) and those with less than a high school education had greater odds of MSP persistence at 8-weeks. In summary, sex differences influence persistent pain via their influence on peritraumatic psychological and pain outcomes in the early-post trauma period, whereas older age and lower education continue to influence worse pain outcomes throughout the first 2 months after trauma, in addition to any association on peritraumatic psychological and pain outcomes.

The majority of MVC characteristics (e.g. collision type, extent of vehicle damage) and patient injury characteristics (e.g. whether the patient's head was hit, injury severity score, whether the individual was admitted vs. discharged) were unrelated to 2- or 8-week MSP (Table 2). Pain severity in the ED predicted both 2- and 8-week MSP, in both crude models and in models that adjusted for socio-demographics, and peri-traumatic distress and dissociation. However, when 2-week pain was also controlled, pain severity in the ED was no longer predictive of 8-week MSP. In other words, the association of pain severity in the ED on 8-week MSP was mediated by 2-week MSP.

3.4 | Associations of peritraumatic symptoms with 2- and 8-week moderate to severe pain

Both peritraumatic distress and dissociation had small but significant positive associations in an additive model predicting 8-week MSP (peritraumatic distress, OR = 1.05; peritraumatic dissociation, OR = 1.02) (Table 3). In addition, both peritraumatic symptom scales significantly predicted 2-week MSP (distress OR = 1.03, dissociation OR = 1.08). However, when 8-week MSP was evaluated while controlling 2-week MSP, only distress was significant (OR = 1.05). In other words, distress and dissociation both predicted early MSP pain symptoms, but only peritraumatic distress predicted 8-week MSP independent of its effect on 2-week MSP. The best-fitting multivariate model for the joint associations of peritraumatic distress and dissociation symptoms with 8-week MSP was an additive model that included linear effects of both predictors. An additive model was also most appropriate as peritraumatic distress and dissociation were correlated with one another ($r = .57$; Pearson correlation) but only weakly correlated with 2-week MSP ($r_{pb} = 0.15\text{--}0.18$) and with 8-week MSP ($r_{pb} = 0.14\text{--}0.19$). Quadratic terms and an interaction term between peritraumatic distress and dissociation were non-significant and consequently were not included in the final model. These associations held

TABLE 3 Associations of peritraumatic distress and dissociation with week 8 self-reported pain^a in the Freeze 1 AURORA MVC sample ($n = 666$)

| | 8-week | | 2-week | | 8-week controlling 2-week ^b | |
|----------------------------|--------|--------------|--------|--------------|--|--------------|
| | OR | (95% CI) | OR | (95% CI) | OR | (95% CI) |
| Peritraumatic distress | 1.05* | (1.02, 1.08) | 1.03 | (0.99, 1.06) | 1.05* | (1.02, 1.08) |
| Peritraumatic dissociation | 1.02 | (0.98, 1.06) | 1.08* | (1.03, 1.14) | 0.99 | (0.95, 1.03) |
| χ^2_2 | 25.0* | | 22.0* | | 10.8* | |

^aThe peritraumatic distress and dissociation scales were both standardized to mean 0 and variance 1, allowing the ORs to be interpreted as the relative odds of pain associated with a one standard deviation difference in peritraumatic symptom scores.

^bControlling for the dichotomous measure of 2-week pain and the continuous 2-week pain symptom scale score.

*Significant at the 0.05 level, two-sided test.

both in crude models and models adjusted for in for socio-demographic, MVC and injury characteristics.

4 | DISCUSSION

Approximately two-thirds of individuals in the present sample experienced moderate or severe MSP 8 weeks after the MVC. This incidence is similar to the results of previous large US ED-based cohort studies (e.g. Feinberg et al., 2017; Linnstaedt et al., 2018), and is consistent with a previously published reports that demonstrated worse pain outcomes after MVC among African Americans versus non-Hispanic white Americans and among those with less educational opportunity/attainment (Beaudoin et al., 2018; McLean et al., 2014). The high incidence of persistent pain in this study suggests that those who come to ED for evaluation after MVC are a group at markedly elevated risk for chronic pain and other APNS. Despite this fact, no screening tools are currently available that could help emergency care providers identify individuals at high risk for APNS; secondary preventive interventions are currently unavailable; and research is lacking on evaluation of candidate interventions to prevent chronic pain development after MVC has been performed. The development of such tools and the identification of treatment targets for future intervention studies is an important goal of the AURORA Study.

The results of this analysis provide important new information regarding the timing of mediating processes for persistent pain development after MVC. Consistent with previous studies, distress and dissociation were associated with acute pain symptoms in the ED e.g., (Beaudoin et al., 2018; Bortsov et al., 2013), as well as persistent pain development (McLean et al., 2014). Interestingly, the association of dissociation with pain persistence appears to be mediated via pain in the early aftermath of trauma, whereas the association between distress on pain persistence occurred between the 2 and 8 weeks periods. These data are consistent with evidence that increased peritraumatic distress is associated with persistent post-traumatic hyperarousal symptoms, and that such hyperarousal symptoms promote the transition from acute to chronic pain during the initial weeks after trauma (Feinberg et al., 2017; Kimerling et al., 2000; Liedl et al., 2010). These data are also consistent with evidence that hyperarousal symptoms, and associated biases towards pain and aversive stimuli, may directly augment pain awareness and experiences (Baum et al., 2011; Liedl & Knaevelsrud, 2008; Sharp & Harvey, 2001). This information may support investigation of interventions that target such things as hyperarousal and their underlying neurobiological systems (e.g. noradrenergic).

The increased incidence of persistent pain among women versus men experiencing MVC observed in this study is consistent with data from many previous studies (Holm

et al., 2009). Our finding that this increased pain vulnerability persists after adjustment for peritraumatic symptoms is consonant with evidence that biological factors (e.g. escape from X-chromosome inactivation [Linnstaedt et al., 2015]), rather than differences in pain reporting alone, play a central role in mediating these differences. The finding in this study that women do not have increased incidence of pain at 2 months, after pain outcome at 2 weeks is adjusted for, is consistent with previous evidence that women on average have better pain coping over time than men (Bortsov et al., 2014).

The fact that older adult MVC survivors have worse pain outcomes over time, even after adjustment for peritraumatic symptoms and pain severity at 2 weeks, is consistent with evidence that older adults have worse outcomes after ED discharge across a broad range of conditions, (LaMantia & Platts-Mills, 2017) including worse pain and functional decline after MVC (Platts-Mills, Flannigan, et al., 2016). Older adults may continue to accrue worse pain outcomes over time in part because they have less access to, or more side effects from, medications that reduce initial pain and help with mobilization (Hunold et al., 2013; Platts-Mills et al., 2018). Older adults also have greater and more persistent reductions in activity after MVC versus younger adults, contributing to worse pain outcomes after the initial post-trauma period (Platts-Mills, Nicholson, et al., 2016). Specific mechanisms mediating worse pain outcomes in older adults remain poorly understood and are an important area of study, given the fact that by 2025, people 65 and older will account for 25% of U.S. drivers (McCracken & Gross, 1998), and that by 2030 over 2 million police reported collisions are projected to involve drivers ≥ 65 years of age (Herndon et al., 2001).

Another important area of study is mechanisms by which lower educational attainment relates to worse pain outcomes, and why the relationship with lower educational attainment, like older age, continues after a first weeks after traumatic stress exposure. Interestingly, lower educational attainment has been found to have a greater relationship to pain outcomes after MVC in some studies than lower income (McLean et al., 2014; Platts-Mills et al., 2012). Lower educational status may influence the transition from acute to persistent pain in a number of ways, including via reducing expectations of recovery, increasing negative cognitions regarding pain (Kim et al., 2014), and altering medication use (Platts-Mills et al., 2012). Further research to understand the specific beliefs, cognitions, and behaviors mediating the influence of lower educational attainment on pain outcomes is important, in order to design optimal preventive interventions. Finally, the fact that ED pain severity, with and without adjustment for sociodemographic factors, predicts persistent pain severity is consistent with the fact that previous studies have found that acute pain severity is the strongest predictor of transition to chronic

pain (Carroll et al., 2008; McLean et al., 2014; Sterling et al., 2005).

In aggregate this information helps us determine which subpopulations (e.g. women) might be important targets for intervention, as well as which factors might be modifiable. Both peritraumatic stress symptoms and acute pain in the ED are potential targets for intervention and have been studied in previous ED-based interventional studies in trauma patients (Gil-Jardine et al., 2018; Sterling et al., 2019). However, it is worth noting that although we detected statistical significant associations, many of these were weak (ORs ranging from 1.02 to 1.08). This implies that even if these targets were modifiable, they may not greatly reduce the burden of the outcome and suggest that other factors may be stronger contributors. In this context it is worth noting that our narrow focus on MVCs might not generalize to other types of trauma. It is possible that distress and dissociation may play a different role in other traumatic events, for instance those with an interpersonal component (e.g. physical or sexual assault).

4.1 | Limitations

Several limitations should be considered when interpreting the above results. Fewer than half of the participants approached in the ED enrolled in the study. While this is understandable given the relatively intensive nature of this year-long deep phenotyping study, the effect of selection bias on generalizability is unknown. However, previous large-scale ED-based studies of pain outcomes after MVC, with much higher consent rates, have found very similar rates of persistent pain 6 to 8 weeks after MVC as the present cohort (Bortsov et al., 2014; Feinberg et al., 2017; Linnstaedt et al., 2018). Second, we evaluated pain persistence at 8 weeks, rather than chronic pain at a later timepoint. While previous studies have shown that pain trajectories and levels of pain are generally established relatively early in the post-trauma period, within the 6–8 week timeframe (Hu et al., 2016; Sterling et al., 2011; Ulirsch, Weaver, et al., 2014), future studies could focus on more distal timepoints to better understand this. Third, this report is a relatively coarse look at pain in the first 8 weeks after MVC, given that survey data were evaluated from only three timepoints (ED, 2 weeks, and 8 weeks). More frequent pain assessments (e.g. several times per week) over a longer follow-up period would likely provide additional insights. As described in detail elsewhere (McLean et al., 2020), AURORA participants completed short daily ‘flash’ surveys using smartphone-based assessments that included periodic marker questions on pain. These data are currently being examined to provide a more textured characterization of changes in pain as part of larger multivariate APNS symptom profiles and trajectories for future analyses.

This additional data collection can also help to augment self-reported standard assessments which can be at risk reporting bias. Lastly, we focus on measures of association, but we have not developed a predictive model, nor have we carried out a statistical mediation analyses. Additional analyses would need to be carried out in order to determine the set of predictors that identify individuals at risk of APNS, including those studied here.

5 | CONCLUSION

This study evaluated the timing of influence of sociodemographic and crash-related factors on pain persistence/severity 8 weeks after MVC, and the degree to which the influence of these factors was mediated by peritraumatic stress symptoms (distress, dissociation) or pain severity at 2 weeks. Peritraumatic stress symptoms appear to exert some influence on both acute pain and the transition from acute to persistent pain, underscoring the interwoven nature of post-traumatic pain and psychological responses and the fact that the early aftermath of an MVC may be an important time period for intervening to prevent/reduce APNS. In addition, results of these analyses suggest important lines of future research regarding the timing and nature of potential mechanisms of pain persistence. These lines of research include investigation of mechanisms by which lower education and older age continue to shape worse pain outcomes after the peritraumatic period, and mechanisms mediating the vulnerability of women to much more severe acute pain responses to traumatic stress, establishing a challenging setpoint for recovery.

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AUTHOR CONTRIBUTIONS

SAM, RCK, KJR and KCK conceptualized the study and were in charge of overall direction and planning. FLB, SAM, SLH, CL, PLH, SS, PIM, ABS, JPH, CWJ, BEP, MSL, RAS, MEM, KM, DAP, CP, RMD, RCM, LDS, NKR and SEB helped with participant recruitment and data collection. RCK, IH, SL and NAS performed the analyses. FLB, SAM, XA, JSS, DZ, TCN, GDC, SDL, SR, RHP, JJ, DB, DAP, JFS, SHE and JME contributed to interpretation of the results and subject matter consultation. FLB and SAM took the lead in writing the manuscript and incorporating the suggestions from all the co-authors. All authors reviewed and provided comments on all sections of the manuscript.

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APPENDIX A

TABLE A1 Univariate and multivariate associations of socio-demographic characteristics with self-reported peritraumatic distress and dissociation in the Freeze 1 AURORA MVC sample ($n = 666$)

| | % | (SE) | Univariate associations | | | | Multivariate associations | | | |
|---------------------------------|------|-------|-------------------------|--------------|--------------|-------------|---------------------------|-------------|--------------|-------------|
| | | | Distress | | Dissociation | | Distress | | Dissociation | |
| | | | b^1 | (95% CI) | b^1 | (95% CI) | b^1 | (95% CI) | b^1 | (95% CI) |
| Age | | | | | | | | | | |
| 50+ | 18.3 | (1.5) | 0.1 | (-0.2, 0.3) | -0.1 | (-0.3, 0.2) | 0.0 | (-0.2, 0.3) | -0.1 | (-0.4, 0.2) |
| 35-49 | 28.7 | (1.8) | 0.1 | (-0.2, 0.3) | -0.1 | (-0.3, 0.1) | 0.1 | (-0.1, 0.3) | -0.1 | (-0.4, 0.1) |
| 25-34 | 30.5 | (1.8) | -0.1 | (-0.3, 0.1) | -0.1 | (-0.3, 0.1) | -0.0 | (-0.2, 0.2) | -0.1 | (-0.3, 0.1) |
| 18-24 | 22.5 | (1.6) | Ref | - | Ref | - | Ref | - | Ref | - |
| $F_{3,660}$ | | | 0.7 | | 0.2 | | 0.4 | | 0.4 | |
| Sex (female) | 73.0 | (1.7) | 0.5* | (0.3, 0.6) | 0.1 | (-0.1, 0.2) | 0.4* | (0.3, 0.6) | 0.1 | (-0.1, 0.2) |
| Race/ethnicity | | | | | | | | | | |
| Non-Hispanic Black | 56.3 | (1.9) | -0.0 | (-0.2, 0.1) | 0.0 | (-0.1, 0.2) | -0.1 | (-0.3, 0.1) | 0.0 | (-0.1, 0.2) |
| Non-Hispanic White | 30.0 | (1.8) | Ref | - | Ref | - | Ref | - | Ref | - |
| Hispanic | 10.5 | (1.2) | 0.0 | (-0.2, 0.3) | 0.0 | (-0.3, 0.3) | -0.0 | (-0.3, 0.3) | 0.0 | (-0.3, 0.3) |
| Other | 3.2 | (0.7) | -0.1 | (-0.6, 0.3) | 0.1 | (-0.4, 0.5) | -0.1 | (-0.6, 0.3) | 0.1 | (-0.3, 0.6) |
| $F_{3,663}$ | | | 0.2 | | 0.0 | | 0.7 | | 0.1 | |
| Marital status | | | | | | | | | | |
| Married/cohabitating | 42.5 | (1.9) | Ref | - | Ref | - | Ref | - | Ref | - |
| Previously married ² | 14.0 | (1.3) | 0.1 | (-0.1, 0.4) | -0.1 | (-0.3, 0.2) | 0.0 | (-0.2, 0.3) | -0.1 | (-0.4, 0.1) |
| Never married | 43.5 | (1.9) | -0.0 | (-0.2, 0.2) | -0.0 | (-0.2, 0.1) | -0.0 | (-0.2, 0.1) | -0.1 | (-0.3, 0.1) |
| $F_{2,663}$ | | | 0.6 | | 0.2 | | 0.1 | | 0.8 | |
| Education | | | | | | | | | | |
| College graduate | 22.1 | (1.6) | Ref | - | Ref | - | Ref | - | Ref | - |
| Some college | 44.0 | (1.9) | 0.1 | (-0.1, 0.3) | 0.1 | (-0.1, 0.3) | 0.1 | (-0.1, 0.3) | 0.1 | (-0.1, 0.3) |
| High school graduate | 24.0 | (1.7) | 0.0 | (-0.2, 0.3) | 0.0 | (-0.2, 0.3) | 0.1 | (-0.2, 0.3) | 0.0 | (-0.2, 0.3) |
| Less than high school | 9.9 | (1.2) | 0.3 | (-0.0, 0.5) | 0.1 | (-0.2, 0.4) | 0.1 | (-0.2, 0.5) | 0.1 | (-0.2, 0.4) |
| $F_{3,662}$ | | | 1.3 | | 0.7 | | 0.3 | | 0.5 | |
| Income³ | | | | | | | | | | |
| More than \$35K | 33.6 | (1.8) | Ref | - | Ref | - | Ref | - | Ref | - |
| \$19-35K | 31.5 | (1.8) | 0.2* | (0.1, 0.4) | 0.2 | (-0.0, 0.4) | 0.2* | (0.0, 0.4) | 0.2 | (-0.0, 0.4) |
| Less than \$19K | 34.8 | (1.8) | 0.2* | (0.0, 0.4) | 0.0 | (-0.2, 0.2) | 0.2 | (-0.1, 0.4) | -0.0 | (-0.2, 0.2) |
| $F_{2,363}$ | | | 3.8* | | 2.2 | | 2.6 | | 2.5 | |
| Employed (yes vs. no) | 77.0 | (1.6) | -0.2* | (-0.4, -0.1) | -0.1 | (-0.3, 0.1) | -0.2 | (-0.4, 0.0) | -0.1 | (-0.3, 0.1) |

¹Standardized to mean = 0 and standard deviation = 1.²Separated, divorced, or widowed.³Family income before taxes.

*Significant at the 0.05 level, two-sided test.

TABLE A2 Univariate and multivariate associations of MVC and injury characteristics with self-reported peritraumatic distress and dissociation in the Freeze 1 AURORA MVC sample ($n = 666$)

| | %/ Mean | (SE) | Univariate associations | | | | Multivariate associations | | | |
|--|----------------|-------------|--------------------------------|-----------------|-------------------------|-----------------|----------------------------------|-----------------|-------------------------|-----------------|
| | | | Distress | | Dissociation | | Distress | | Dissociation | |
| | | | b^1 | (95% CI) | b^1 | (95% CI) | b^1 | (95% CI) | b^1 | (95% CI) |
| Role in MVC | | | | | | | | | | |
| Passenger | 23.3 | (1.6) | 0.1 | (-0.1, 0.3) | 0.1 | (-0.1, 0.3) | 0.0 | (-0.2, 0.2) | -0.0 | (-0.2, 0.2) |
| Driver with others | 19.2 | (1.5) | 0.2 | (-0.0, 0.4) | 0.2 | (-0.0, 0.4) | 0.1 | (-0.1, 0.3) | 0.1 | (-0.1, 0.3) |
| Driver alone | 57.5 | (1.9) | Ref | - | Ref | - | Ref | - | Ref | - |
| $F_{2,663}$ | | | 1.8 | | 1.3 | | 0.6 | | 0.3 | |
| Your vehicle collided with | | | | | | | | | | |
| Other moving vehicle | 68.2 | (1.8) | 0.3* | (0.1, 0.5) | 0.1 | (-0.1, 0.3) | 0.2 | (-0.0, 0.4) | 0.0 | (-0.2, 0.2) |
| Stationary object | 17.9 | (1.5) | 0.3 | (-0.0, 0.5) | 0.0 | (-0.3, 0.3) | 0.1 | (-0.1, 0.4) | -0.1 | (-0.4, 0.1) |
| Other ² | 14.0 | (1.3) | Ref | - | Ref | - | Ref | - | Ref | - |
| $F_{2,663}$ | | | 3.1* | | 0.4 | | 1.9 | | 1.3 | |
| Damage to your vehicle | | | | | | | | | | |
| Severe | 58.3 | (1.9) | 0.6* | (0.3, 1.0) | 0.4* | (0.1, 0.7) | 0.6* | (0.3, 0.9)* | 0.3* | (0.0, 0.6) |
| Moderate | 26.4 | (1.7) | 0.2 | (-0.1, 0.5) | 0.1 | (-0.3, 0.4) | 0.2 | (-0.1, 0.6) | 0.1 | (-0.2, 0.4) |
| Minor | 8.9 | (1.1) | -0.1 | (-0.4, 0.3) | -0.1 | (-0.5, 0.3) | 0.0 | (-0.3, 0.4) | -0.0 | (-0.4, 0.4) |
| Other ³ | 6.5 | (1.0) | Ref | - | Ref | - | Ref | - | Ref | - |
| $F_{3,662}$ | | | 17.0* | | 9.1* | | 10.5* | | 4.3* | |
| Passengers with injuries (0-4 standardized) ⁴ | 0.0 | (0.0) | 0.1* | (0.0, 0.2) | 0.1* | (0.0, 0.2) | 0.0 | (-0.1, 0.1) | 0.1 | (-0.0, 0.2) |
| Others with injuries (any vs. none) ⁴ | 10.2 | (1.2) | 0.2 | (-0.1, 0.4) | 0.2 | (-0.1, 0.4) | -0.0 | (-0.3, 0.2) | -0.0 | (-0.3, 0.2) |
| Transportation to ED | | | | | | | | | | |
| Ambulance | 58.0 | (1.9) | 0.4* | (0.2, 0.6) | 0.3* | (0.2, 0.5) | 0.3* | (0.1, 0.5) | 0.2* | (0.0, 0.4) |
| Other immediately | 14.7 | (1.4) | 0.0 | (-0.2, 0.3) | 0.1 | (-0.1, 0.4) | 0.1 | (-0.1, 0.3) | 0.2 | (-0.1, 0.4) |
| Other delay | 27.3 | (1.7) | Ref | - | Ref | - | Ref | - | Ref | - |
| $F_{2,663}$ | | | 13.6* | | 7.5* | | 6.8* | | 2.9 | |
| Personal injury | | | | | | | | | | |
| Hit head (yes vs. no) | 57.4 | (1.9) | 0.3* | (0.1, 0.4) | 0.4* | (0.2, 0.5) | -0.0 | (-0.2, 0.1) | 0.1 | (-0.1, 0.2) |
| TBI (yes vs. no) | 27.5 | (1.7) | 0.5* | (0.3, 0.6) | 0.6* | (0.4, 0.8) | 0.3* | (0.1, 0.5) | 0.4* | (0.2, 0.6) |
| AIS-Max ⁵ (2+ vs. 1) | 13.1 | (1.3) | -0.0 | (-0.3, 0.2) | 0.1 | (-0.1, 0.4) | -0.1 | (-0.3, 0.1) | 0.0 | (-0.2, 0.3) |
| Admitted (yes vs. no) | 4.1 | (0.8) | 0.1 | (-0.3, 0.5) | 0.2 | (-0.1, 0.6) | -0.0 | (-0.4, 0.4) | 0.1 | (-0.2, 0.5) |
| Severity of pain (mean) ⁶ | 0.0 | (0.0) | 0.2* | (0.1, 0.3) | 0.1* | (0.0, 0.2) | 0.2* | (0.1, 0.2) | 0.1 | (-0.0, 0.1) |
| Severity of other somatic symptoms (mean) ⁷ | 0.0 | (0.0) | 0.2* | (0.1, 0.3) | 0.2* | (0.1, 0.2) | 0.1* | (0.0, 0.2) | 0.1* | (0.0, 0.2) |

¹Standardized to mean = 0 and standard deviation = 1.

²No collision ($n = 81$), "other" ($n = 8$), and "don't know" ($n = 8$).

³None ($n = 12$) and "don't know" ($n = 31$).

⁴Moderate or severe injuries.

⁵Max score of the nine AIS regions.

⁶Self-reported 0-10 scale on pain intensity right now, standardized to mean = 0 and standard deviation = 1.

⁷Sum of all differences in each somatic symptom between 30-day (self-reported 0-10 scale) and right now (self-reported 0-10 scale), standardized to mean = 0 and standard deviation = 1.

*Significant at the 0.05 level, two-sided test.

TABLE A3 Associations of baseline, 2-, and 8-week measures with patterns of sample attrition among respondents who completed the baseline assessment

| | All | | ED Only | | ED + WK2 Only | | ED + WK8 Only | | ED + WK2 + WK8 Only | | χ^2/F -test |
|----------------------------------|------------------|-------|------------------|-------|------------------|-------|------------------|-------|---------------------|-------|------------------|
| | Est ^a | SE | Est ^a | SE | Est ^a | SE | Est ^a | SE | Est ^a | SE | |
| I. Demographics | | | | | | | | | | | |
| Male (%) | 31.6 | (1.5) | 41.0 | (3.5) | 40.0 | (4.5) | 35.7 | (7.4) | 27.0 | (1.7) | 18.9* |
| Age (%) | | | | | | | | | | | 36.2* |
| 50+ | 15.5 | (1.1) | 12.5 | (2.3) | 3.3 | (1.6) | 19.0 | (6.1) | 18.3 | (1.5) | 19.4* |
| 35–49 | 26.2 | (1.4) | 19.0 | (2.8) | 23.3 | (3.9) | 28.6 | (7.0) | 28.7 | (1.8) | 8.1* |
| 25–34 | 33.0 | (1.5) | 38.5 | (3.4) | 41.7 | (4.5) | 21.4 | (6.3) | 30.5 | (1.8) | 11.3* |
| 18–24 | 25.4 | (1.4) | 30.0 | (3.2) | 31.7 | (4.2) | 31.0 | (7.1) | 22.5 | (1.6) | 8.3* |
| Race-ethnicity (%) | | | | | | | | | | | 13.9 |
| Non-Hispanic Black | 55.3 | (1.6) | 52.0 | (3.5) | 52.5 | (4.6) | 69.0 | (7.1) | 55.9 | (1.9) | 4.6 |
| Non-Hispanic White | 29.1 | (1.4) | 28.5 | (3.2) | 30.0 | (4.2) | 14.3 | (5.4) | 30.0 | (1.8) | 4.8 |
| Hispanic | 12.2 | (1.0) | 14.5 | (2.5) | 16.7 | (3.4) | 14.3 | (5.4) | 10.5 | (1.2) | 5.2 |
| Other | 3.5 | (0.6) | 5.0 | (1.5) | 0.8 | (0.8) | 2.4 | (2.4) | 3.6 | (0.7) | 4.0 |
| Marital status (%) | | | | | | | | | | | 13.5* |
| Married/cohabitating | 41.1 | (1.5) | 39.5 | (3.5) | 36.7 | (4.4) | 40.5 | (7.6) | 42.5 | (1.9) | 1.7 |
| Previously married | 12.0 | (1.0) | 9.5 | (2.1) | 5.8 | (2.1) | 9.5 | (4.5) | 14.0 | (1.3) | 8.2* |
| Never married | 46.9 | (1.6) | 51.0 | (3.5) | 57.5 | (4.5) | 50.0 | (7.7) | 43.5 | (1.9) | 9.9* |
| Education (%) | | | | | | | | | | | 31.6* |
| College graduate or more | 18.4 | (1.2) | 13.5 | (2.4) | 10.0 | (2.7) | 7.1 | (4.0) | 22.1 | (1.6) | 18.4* |
| Some college | 43.2 | (1.5) | 38.5 | (3.4) | 46.7 | (4.6) | 42.9 | (7.6) | 44.0 | (1.9) | 2.6 |
| High school graduate | 26.7 | (1.4) | 30.0 | (3.2) | 30.8 | (4.2) | 40.5 | (7.6) | 24.0 | (1.7) | 8.7* |
| Not high school graduate | 11.8 | (1.0) | 18.0 | (2.7) | 12.5 | (3.0) | 9.5 | (4.5) | 9.9 | (1.2) | 10.0* |
| Income (%) | | | | | | | | | | | 0.8 |
| More than \$35k | 34.1 | (1.7) | – | – | 32.5 | (4.3) | – | – | 34.4 | (1.8) | 0.2 |
| \$19k to \$35k | 31.4 | (1.7) | – | – | 35.0 | (4.4) | – | – | 30.8 | (1.8) | 0.8 |
| Less than \$19k | 34.5 | (1.7) | – | – | 32.5 | (4.3) | – | – | 34.8 | (1.8) | 0.2 |
| Employed (%) | 77.6 | (1.5) | – | – | 80.8 | (3.6) | – | – | 77.0 | (1.6) | 0.8 |
| II. Pre-MVC APNS | | | | | | | | | | | |
| Global pain diagnosis (%) | 31.5 | (1.4) | 32.0 | (3.3) | 33.3 | (4.3) | 40.5 | (7.6) | 30.5 | (1.8) | 2.1 |
| Global pain severity (M) | –0.0 | (0.0) | –0.0 | (0.1) | 0.0 | (0.1) | 0.3 | (0.2) | –0.0 | (0.0) | 1.6 |
| Body region pain severity (M) | –0.0 | (0.0) | –0.1 | (0.1) | –0.1 | (0.1) | 0.5 | (0.2) | –0.0 | (0.0) | 3.8* |
| Somatic symptom severity (M) | –0.0 | (0.0) | 0.1 | (0.1) | –0.0 | (0.1) | 0.5 | (0.2) | –0.0 | (0.0) | 4.4* |
| III. MVC characteristics | | | | | | | | | | | |
| Role in vehicle (%) | | | | | | | | | | | 7.6 |
| Passenger | 24.6 | (1.3) | 28.5 | (3.2) | 25.0 | (4.0) | 26.2 | (6.8) | 23.3 | (1.6) | 2.3 |
| Driver, alone | 55.1 | (1.6) | 51.5 | (3.5) | 51.7 | (4.6) | 42.9 | (7.6) | 57.5 | (1.9) | 5.7 |
| Driver, with others | 20.3 | (1.3) | 20.0 | (2.8) | 23.3 | (3.9) | 31.0 | (7.1) | 19.2 | (1.5) | 4.1 |
| Severity of vehicular damage (%) | | | | | | | | | | | 6.2 |
| Severe | 58.8 | (1.5) | 59.0 | (3.5) | 60.0 | (4.5) | 61.9 | (7.5) | 58.3 | (1.9) | 0.3 |

(Continues)

TABLE A3 (Continued)

| | All | | ED Only | | ED + WK2 Only | | ED + WK8 Only | | ED + WK2 + WK8 Only | | χ^2/F -test |
|--------------------------------------|------------------|-------|------------------|-------|------------------|-------|------------------|-------|---------------------|-------|------------------|
| | Est ^a | SE | Est ^a | SE | Est ^a | SE | Est ^a | SE | Est ^a | SE | |
| Moderate | 26.3 | (1.4) | 26.5 | (3.1) | 28.3 | (4.1) | 16.7 | (5.8) | 26.4 | (1.7) | 2.3 |
| Minor | 9.1 | (0.9) | 9.5 | (2.1) | 9.2 | (2.6) | 11.9 | (5.0) | 8.9 | (1.1) | 0.5 |
| No damage/missing | 5.8 | (0.7) | 5.0 | (1.5) | 2.5 | (1.4) | 9.5 | (4.5) | 6.5 | (1.0) | 4.2 |
| Transportation to ED | | | | | | | | | | | 6.0 |
| Not direct | 28.4 | (1.4) | 27.0 | (3.1) | 34.2 | (4.3) | 35.7 | (7.4) | 27.3 | (1.7) | 3.6 |
| Other direct | 14.8 | (1.1) | 17.5 | (2.7) | 13.3 | (3.1) | 7.1 | (4.0) | 14.7 | (1.4) | 3.3 |
| Ambulance | 56.8 | (1.5) | 55.5 | (3.5) | 52.5 | (4.6) | 57.1 | (7.6) | 58.0 | (1.9) | 1.4 |
| Personal injuries | | | | | | | | | | | |
| Hit Head (self-reported) | 49.0 | (1.6) | 49.5 | (3.5) | 50.0 | (4.6) | 47.6 | (7.7) | 48.8 | (1.9) | 1.7 |
| Inpatient admission versus discharge | 4.0 | (0.6) | 2.0 | (1.0) | 6.7 | (2.3) | 4.8 | (3.3) | 4.1 | (0.8) | 4.4 |
| Injuries of others | | | | | | | | | | | |
| Number injured in vehicle (M) | -0.0 | (0.0) | 0.0 | (0.1) | -0.0 | (0.1) | 0.3 | (0.2) | -0.0 | (0.0) | 1.3 |
| Injuries outside vehicle | 9.6 | (0.9) | 9.0 | (2.0) | 7.5 | (2.4) | 9.5 | (4.5) | 10.2 | (1.2) | 1.0 |
| IV. Peritraumatic APNS | | | | | | | | | | | |
| Peritraumatic distress (M) | -0.0 | (0.0) | -0.2 | (0.1) | -0.0 | (0.1) | 0.2 | (0.2) | 0.0 | (0.0) | 3.2* |
| Peritraumatic dissociation (M) | -0.0 | (0.0) | -0.1 | (0.1) | 0.0 | (0.1) | 0.2 | (0.2) | 0.0 | (0.0) | 1.3 |
| Global pain diagnosis (%) | 88.0 | (1.0) | 89.5 | (2.2) | 86.7 | (3.1) | 92.9 | (4.0) | 87.5 | (1.3) | 1.7 |
| Global pain severity (M) | -0.0 | (0.0) | 0.0 | (0.1) | -0.1 | (0.1) | 0.3 | (0.2) | -0.0 | (0.0) | 1.3 |
| Body region pain severity (M) | -0.0 | (0.0) | -0.0 | (0.1) | -0.0 | (0.1) | 0.2 | (0.2) | -0.0 | (0.0) | 0.9 |
| Count of CSNW body region pain (M) | -0.0 | (0.0) | 0.0 | (0.1) | 0.0 | (0.1) | -0.1 | (0.1) | -0.0 | (0.0) | 0.1 |
| Somatic symptom severity (M) | -0.0 | (0.0) | 0.0 | (0.1) | 0.0 | (0.1) | 0.4 | (0.2) | -0.0 | (0.0) | 2.4 |
| V. Two-week APNS | | | | | | | | | | | |
| Global pain diagnosis (%) | 80.7 | (1.4) | - | - | 76.7 | (3.9) | - | - | 81.4 | (1.5) | 1.4 |
| Global pain severity (M) | -0.0 | (0.0) | - | - | -0.1 | (0.1) | - | - | 0.0 | (0.0) | 1.2 |
| Count of CSNW body region pain (M) | -0.0 | (0.0) | - | - | -0.1 | (0.1) | - | - | 0.0 | (0.0) | 1.4 |
| VI. Eight-week APNS | | | | | | | | | | | |
| Global pain diagnosis (n) | 67.1 | (1.8) | - | - | - | - | 61.9 | (7.5) | 67.4 | (1.8) | 0.5 |
| | (1,028) | | (200) | | (120) | | (42) | | (666) | | |

Abbreviation: CSNW, clinically significant, new, or worsening.

^aEntries are either percentages (%) or standardized means (M).

*Significant difference across subgroups the 0.05 level, two-sided test.