Psychologic Processes in Daily Life With Chronic Whiplash: Relations of Posttraumatic Stress Symptoms and Fear-of-pain to Hourly Pain and Uptime

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Objectives: Recent models of the relationship between posttraumatic stress and whiplash pain suggest that psychological stress relating to a motor vehicle crash may influence pain perception. The mechanisms of this relationship may be through more direct, psychological pathways, or through factors proposed by the fear-avoidance models of chronic pain. This study sought to investigate the relative contribution of fear-of-pain and trauma symptomatology to daily pain and time spent in an upright posture (uptime) in chronic whiplash-associated disorder (WAD).

Methods: Hourly electronic-diary reports were used to explore the within-day relationship of psychological trauma symptoms and fear-of-pain to same-hour and next-hour pain reports and next-hour uptime (measured by accelerometers) in 32 individuals with a chronic WAD. Within-person effects were analyzed for 329 diary entries using multilevel modeling with fixed slopes and random intercepts.

Results: Reports of trauma-related hyperarousal were associated with greater same-hour pain, and this relationship was mediated by fear-of-pain. Fear-of-pain and uptime were independently associated with reports of increased next-hour pain (controlling for first-order serial autocorrelation). Fear-of-pain was unrelated to next-hour uptime, but trauma-related avoidance symptoms were associated with reduced uptime. This study supports the relationship between psychological trauma responses and pain, suggesting behavioral (avoidance) pathways and effects on pain perception through fear-of-pain. These findings reinforce the need to evaluate traumatic stress as a factor in recovery from WAD.

Key Words: whiplash associated disorders, posttraumatic stress, within-person analyses, multilevel modeling

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Whiplash associated disorders (WAD) are complex conditions manifested by both physical (biological) and psychologic factors[1] and there are likely to be interactions between these factors.[2,3] The traumatic nature of the onset of injury (motor vehicle crash-MVC) may be an important factor in the development of chronic pain and disability after whiplash injury.[4,5] It has been found that injured people with ongoing moderate or greater pain and disability 6-months post-MVC were characterized by a moderate posttraumatic stress (PTS) response that was apparent from the acute stage and persisted into chronicity.[5]

There is growing interest in the relationship between PTS and chronic pain.[6,7] McLean et al[2] propose a neurobiologic stress model of post-MVC pain to describe possible mechanisms by which PTS reactions may influence pain and neurobiologic processes through stress system responses. For example, they suggest that stress system activation may influence descending pain modulation in the prefrontal cortex, antinociceptive mechanisms in the dorsal horn, or peripheral proinflammatory cytokines. They also suggest alternative cognitive and behavioral mechanisms described in the fear-avoidance (FA) models,[8] such as pain catastrophising, fear-of-pain, and behavioral avoidance. Traumatized individuals may be more prone to physical deconditioning because of reduced activity-levels resulting from efforts to avoid reminders of the traumatic event (which may include pain itself), or they may be sensitized to respond to pain with fear or appraise it in catastrophic terms.[6,7] So, fear-of-pain and behavioral avoidance may mediate the effects of PTS on pain.

According to FA models, fear-of-pain, movement, or reinjury contributes to physical deconditioning and the eventual "disuse syndrome"[9] by promoting avoidance of movement or usual activities. It may also contribute to perceived pain more directly, such as through attention to pain[10] or psychological arousal including muscle tension.[11]

This study seeks to investigate the relative contribution of fear-of-pain and trauma symptomatology (avoidance, hyperarousal, and intrusion) to daily pain and physical activity in chronic WAD by using ecologic monetary assessment methods through electronic diary (ED) monitoring and activity data from accelerometers. Ecologic monetary assessment allows investigation of phenomena at the moment they occur in natural settings[12] thus minimizing retrospective recall bias.[13] It also allows exploration of within-person relationships between physical and psychologic factors. It is anticipated that during the course of the day fear-of-pain will be associated with reduced next-hour time spent in an upright posture (uptime), and possibly with increased reports of pain in the same or next hour. Uptime was used in preference to overall activity as upright posture is often problematic for people with neck pain. Of interest is whether reports of PTS symptoms related to the MVC will be associated with reports of increased same or next hour pain and possibly with decreased uptime during the next hour. Finally, in which both trauma symptoms and fear-or-pain are related to pain reports or uptime the possibility of a mediation model will be tested.

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MATERIALS AND METHODS

Participants

Participants consisted of 32 volunteers (5 males), aged 22 to 64 (M = 40.8, SD = 10.1), reporting neck pain as a result of an MVC. Participants were recruited through general advertisement, through the university clinic and from private medical and physiotherapy practices. They were considered eligible if they met Quebec task force (QTF)[14] classifications of WAD grade II and lived within traveling distance of the University, and were excluded if they experienced concussion, loss of consciousness, or head injury as a result of the MVC, or reported a prior whiplash injury or a history of neck-complaints requiring treatment. Time since the MVC ranged from 3 to 36 months (M = 18.2, SD = 12.7). A total of 45 individuals initially volunteered for the study. Of these 11 were not prepared to undertake the study owing to time or travel constraints and 2 did not meet the inclusion criteria (1 was WAD grade III and 1 reported associated head injuries with the MVC).

A majority of participants were either self-employed (n = 15) or employed (n = 14). Of these individuals, 59% were working the number of hours they usually worked, 31% had reduced their usual hours of work owing to their whiplash condition, and 10% were not working because of their injury. Two of the remaining participants reported doing home-duties and 1 was retired. Eighteen participants reported being involved in litigation, with 3 of those having had their claim settled.

All participants gave informed consent for their participation. They were remunerated for transport costs to the research unit. The study was approved by the University's Medical Research Ethics Committee.

Questionnaires

Injury-related and demographic details were recorded for descriptive purposes. In addition, a number of established scales were administered for the purpose of cross-validating ED scales against standard measures of the same or similar constructs.

Neck Pain and Disability

The Neck Disability Index (NDI)[15] is a 10-item scale measuring neck-pain intensity, headaches, and the impact of pain on daily functional activities. The reliability and validity of the scale is well-established and it is a frequently used outcome measure of neck pain and pain-related disability.[16] A total score out of 100 is calculated by summing scores for each item (0 = no pain/disability to 5 = maximum pain/disability) and multiplying by 2. In this study, participants were compared with all measures according to recovery status, defined by NDI score as either mild pain/disability (10 to 28 NDI) or moderate/severe pain and disability (30 or greater NDI) according to established cut-points.[15] In this study no participants fell within the "recovered" range (below 8 NDI). The range of possible scores is 0% to 100%.

Fear of Movement

The Tampa scale of Kinesphobia (TSK) is an established measure of fear of reinjury owing to movement, with known reliability and validity.[17] It consists of 17 items relating to beliefs about exercise and pain. Four responses ranging from strongly disagree (1) to strongly agree (4) are available for each item.[17] Four items are reversed scored and the final score for each item is summed to give a total score 17 to 68, with higher scores indicating greater levels of kinesphobia. In this study the TSK was used as a measure against which to validate the diary-based fear-of-pain scale.

Pain Catastrophising

The Catastrophising Scale of the Coping Strategy Questionnaire (CSQ-C)[18] is a well-established measure of catastrophic appraisals of pain (eg, "It is awful and I feel that it overwhelms me"). Its 7 items are measured on a 7-point Likert scale (0 = never, 3 = sometimes, 6 = always) indicating the frequency of each response to pain. The CSQ-C was used in this study as a measure against which to validate the diary-based fear-of-pain scale. The possible range of scores is 0 to 42.

Trauma Symptomatology

The Impact of Event Scale—Revised (IES-R)[19] is a 22-item scale measuring 3 classes of symptomatology resulting from a psychologically traumatic incident—*avoidance* (8 items), *intrusion* (8 items), and *hyperarousal* (6 items). Respondents indicate the degree to which they were distressed or bothered by symptoms on a 5-point (0 = Not at all to 4 = Extremely) scale. The IES-R yields a total score (ranging from 0 to 88). The investigators recommend using means instead of raw sums for each of these subscales scores.[19] The IES-R is a frequently used measure of psychological trauma symptomatology with showed adequate psychometric properties.[20] It was used in this study as a means of validating the diary-based trauma symptom scales.

Electronic Diary (ED)

Electronic diaries were used to measure momentary within-day reports of pain and fear-of-pain, and trauma-symptoms during the prior hour. Daily-diary methods promise to reveal processes that occur within people in the course of daily life.[21] In addition, daily-diary studies that analyze lagged effects over time (such as across hours or across days) are able to make stronger arguments about causality.[22]

The ED required participants to respond to questions using a stylus-pen on the touch-sensitive screen of a Dell Axim ×50 personal organizer (or, PDA). The ED contained 30 screens involving a range of questions about pain, emotional states, behavior and activities, and pain coping and appraisals. Only those items related to this study are described and reported here. The pain and fear-of-pain items employed a Verbal Rating Scale (VRS) -type format whereby participants selected a point on a 100-point line (recorded as a value between 0 and 1) using the PDA's stylus pen. At equal intervals along the rating scale verbal descriptors were provided to help participants anchor their responses (Table 1). Participants were prevented from continuing to the next item until they had responded to the VAS scale. The trauma measures employed a check-list of format whereby one, all, or any combination of options could be selected from a list of symptoms. Once they had completed an item participants were prevented from returning to earlier items.

Pain Intensity

Current neck pain was measured on a single Verbal rating scale (VRS) with sliding response option, "The level of my neck pain at the present moment is:". Feedback

TABLE 1. Electronic Diary Scales, Items, and Feedback Anchors Terms

Scale	Question and Feedback
Pain	A single VRS item: "The level of my neck pain at the present moment is:" Feedback anchors: not noticeable; just noticeable; very weak; weak; mild; moderate; strong; intense; very strong; severe; very intense; excruciating
Fear of pain	An average of six VRS-type items: "Right now my pain makes me feel fearful" Feedback anchors: very slightly or not at all; a little; moderately; quite a bit; very much "At the moment I have to restrict my movements to avoid injuring myself or making my pain worse" Feedback anchors: as above "I become anxious thinking about what my pain will be like over the next hour" Feedback anchors: as above "The pain is terrible and I feel it is never going to get any better" Feedback anchors: strongly disagree; somewhat disagree; somewhat agree; strongly agree "I feel I can't stand the pain any more" Feedback anchors: as above "Something serious could happen because of my activities over the next hour (eg, injuring myself and/or worsening my condition)" Feedback anchors: as above
Trauma symptoms	Three checklist-type screens, each with the question: "with respect to the accident, which difficulties distressed or bothered me since the previous entry?" Intrusion Checklist options: Other things making me think about it; I thought about it without meaning to; Pictures about it popped into my mind; I had waves of strong feelings about it; Reminders brought back feelings of it Hyperarousal Checklist options: I was jumpy and easily startled; I had trouble concentrating; I felt watchful or on-guard; Reminders led to sweating, nausea, racing heart, trouble breathing, or another physical reaction; I felt irritable and angry Avoidance Checklist options: I tried not to talk about it; I tried to remove it from my memory; I tried not to think about it; I didn't deal with my feelings about it; I stayed away from reminders of it

anchors were based on Tursky, Jamner & Friedman's (1982; cited in Karoly & Jensen, 1987) 12-point VRS (Table 1).

Fear-of-Pain

Six items relating to fear-of-pain were measured on VRS with sliding response option (Table 1). Two items were constructed to measure fear of movement and reinjury ["At the moment I have to restrict my movements to avoid injuring myself or making my pain worse" and "Something serious could happen because of my activities over the next hour (eg, injuring myself and/or worsening my condition)"]. Two items were constructed to measure fear of current pain ("Right now my pain makes me feel fearful") and anxiety about potential pain ("I become anxious thinking about what my pain will be like over the next hour") in a face valid way. Two items measuring pain catastrophising ("My pain is terrible and I feel it is never going to get any better," and "I feel I can't stand the pain any more") were adapted from the 2 items from the coping strategy questionnaire[18] identified by Jensen et al[23] as the best brief measure of pain catastrophising. These items were originally selected to allow for the separate assessment of pain catastrophising and fear-of-pain, however, a principal components analysis of all diary entries (n = 546) revealed a single factor accounting for 81.5% of variance. All items loaded between 0.88 and 0.96, except the fear-of-injury item (0.7). All fear-related and catastrophising items were combined in a single fear-of-pain variable, consistent with notions of fear-of-pain and catastrophising as separate aspects of a cognitive-affective fear complex.[24]

Trauma Symptomatology

The 5 items with highest item-total correlations from the IES-R hyperarousal, avoidance, and intrusion scales were selected to measure those 3 constructs on the ED, based on data from a earlier study of WAD patients.[25] Sleep-related items were not considered for inclusion because they would not be relevant for the majority of diary entries when sleep had not occurred during the earlier hour. IES-R items 8, 11, 12, 17, and 22 were chosen from the Avoidance scale, 1, 3, 6, 9, and 16 from the Intrusions scale, and 4, 10, 18, 19 and 21 from the Hyperarousal scale. In the pilot dataset, scales based on those items correlated $r = 0.85$, $r = 0.82$, and $r = 0.83$, respectively with the total scales. On the ED, trauma-related symptoms were presented over 3 checklist-type diary screens with a total of 15 options (Table 1). On each screen participants were asked "With respect to the accident, which difficulties distressed or bothered me since the previous entry?" The number of endorsed items for each scale was summed to obtain a total score.

Objective Measures of Activity

The Lifeshirt system (Vivometrics, CA) includes accelerometers to measure movement over x-axes and y-axes. Once the Lifeshirt is fitted to the participant, the accelerometers were calibrated to a known posture—in this case sitting/standing while the participant was in an upright posture. Lifeshirt output includes a measure of posture that was used to calculate the proportion of time spent in an upright posture (uptime). We purposely opted to use this measure rather than overall activity for 2 reasons. First upright posture, particularly sitting is often problematic for people with neck pain and second as we were collecting data across hours measurement of uptime may be more appropriate than general activity measures. Electrocardiogram (ECG) and respiration were also measured although they are not reported here. Uptime was calculated as the proportion of time spent in an upright posture (standing or sitting) during a 30-minute period between diary entries—from quarter past each hour to quarter-to-the next hour.

Procedure

Participants attended the research centre, in which they underwent sensory testing as conducted in prior studies,[25] which will be reported elsewhere. They were fitted with the Lifeshirt system, and the process of fitting the system was showed to them. Participants were guided through 1 entry of the ED to familiarize them with the process and the diary items. Participants wore the Lifeshirt for at least 1 day, between 10:15 AM and 8:45 PM, although they were encouraged to refit the Lifeshirt the next day for the same time-period. Preferably, their initial assessment was scheduled for approximately 8:00am and they wore the Lifeshirt home from that session, although when this was not possible they fitted the Lifeshirt themselves on the next day.

On the same days participants wore the Lifeshirt they were asked to complete the ED. EDs were programmed to "wake themselves up" to emit alarms every hour between 11:00 AM and 8:00 PM at a random time ± 15 minutes either side of each hour. Alarms consisted of a "bell"-type alert that sounded continuously for 1 minute and then on the minute for the next 9 minutes. After that time the diary put itself back to sleep until the next hour's alarm.

When an alarm was sounded the PDA opened a screen providing participants with options to open, dismiss, or postpone the diary entry. Open activated the electronic diary, dismiss cancelled the entry, and postpone allowed the participant to choose a period between 5 and 15 minutes to postpone the entry.

The diary emitted an alarm each minute if it was left unattended during an entry. It put itself to sleep, terminating the current entry, if it was left unattended for 4 minutes.

Data Structure and Analysis

Separate data files were created in SPSS 15.0 for level 1 (within-person diary-entry level) and level 2 (person level) data. Each row in the level 1 file represented 1 diary entry. On each row, pain ratings from the subsequent row were inserted as next-hour values (provided entries were made by the same person). To allow valid comparisons across hours, entries were deleted if the lag between same-hour and next-hour entries exceeded 90 minutes (the maximum possible time between adjoining PDA alarms). Diary entries were matched to uptime data from the 30-minute windows before (same hour) and after (next hour) each diary entry. Diary entries without corresponding preentry and postentry accelerometer data were deleted.

Analyses were performed through multilevel modeling (MLM) using HLM5.0[26] with restricted maximum likelihood estimation. Unlike standard regression in which total variance is examined, in MLM variance is partitioned into level 2 (variance between people) and level 1 (variance within people) variance. The variance components (or empty) model is an initial step in MLM analyses. It contains no predictors and shows the proportion of total variance attributable to level 1 versus level 2 variance.

If diary-level data were used in conventional correlational analyses inferential statistics would be misestimated because of violation of the assumption of independence of observations (diary entries from 1 person are more likely to be similar than diary entries from separate people). In this study a random intercept model was used to overcome this problem by treating individual's intercepts (mean values on

TABLE 2. Descriptive Statistics per Subject and for All Within-person Data-points

	Per Person (n = 32)		Across all Participants (n = 329)	
	M	SD	M	SD
Months since injury	27.15	19.69		
VAS pain (0-10)	4.8	2.3		
TSK	40	9.65		
IES-R				
Avoidance	0.87	0.89		
Intrusion	1.05	1.09		
Hyper-arousal	1.16	1.11		
Total	1.02	1		
CSQ				
Catastrophising	11.16	8.83		
Electronic diary (mean scores)				
Pain Intensity	0.37	0.23	0.37	0.25
Fear-of-pain	0.22	0.23	0.23	0.24
Trauma-Intrusion	0.12	0.20	0.12	0.21
Hyper-arousal	0.19	0.24	0.18	0.25
Avoidance	0.12	0.15	0.11	0.17
Mean uptime (proportion of 30 mins)	0.76	0.22	0.74	0.34

CSQ indicates Coping Strategies Questionnaire; IES-R, Impact of Events Scale-Revised; TSK, Tampa Scale of Kinesiphobia.

the outcome variable) as random effects, thereby removing between-person differences.[27]

As this study is concerned with within-person predictors of within-person outcomes, the focus of analyses is on the proportion of within-person variance accounted for. However, the coefficients of diary-level predictors may confound within-person effects (reflecting effects on outcomes attributable to hour-by-hour variation in predictors) with between-person effects (because individuals will differ in mean values on diary-level predictors). To isolate the within-person effects of predictors all level 1 predictors were centered around their means to remove between-person variation.[28]

In an initial set of analyses predictors were entered with random slopes to test the hypothesis that within-day processes may differ between individuals with high versus low levels of pain and disability (measured by the NDI). However, NDI scores did not predict within-day slopes, so all level 1 predictors were entered with fixed slopes.

The linear effect of time-of-day was assessed for each outcome to rule out possible confounding effects. No significant effects were found for any outcome, so time-of-day was not entered into subsequent analyses.

The temporal structure of the data is illustrated in Figure 1, along with an outline of the source of data for each of the 3 sets of analyses for same-hour pain, next-hour pain, and next-hour uptime. Analyses were conducted in a standard order for each outcome variable.

In a first set of analyses (Table 3) the outcome variable was same-hour pain. An empty model was computed in which no predictors were entered and the total variance at levels 1 and 2 could be examined. All subsequent models were compared with this model to examine variance-accounted for by predictors. In a series of separate analyses predictors (fear-of-pain, trauma symptoms, and uptime) were added with random intercepts to the empty model. The 3 trauma scales were entered together. Finally, if more than 1 predictor was found to significantly predict the same-hour pain a full model was computed in which all significant predictors were added together as fixed effects.

In a second set of analyses (Table 5) the outcome variable was next-hour pain. After computing an empty model a comparison model was calculated in which the effects of change in pain over the hour was controlled by entering same-hour pain as a predictor. All subsequent analyses were compared with this comparison model to examine variance-accounted-for by predictors after removing the first-order serial autocorrelation effect.[22,29] Again, all predictors were entered into separate analyses to determine their independent effect upon next-hour pain before a full model into which all significant predictors were entered.

In the third set of analyses (Table 6) the outcome was next-hour uptime. The same sequence of analyses were conducted as for next-hour pain (including controlling for same-hour uptime in a comparison model), with pain, fear-of-pain, and trauma symptoms as predictors. If, in any set of analyses, both fear-of-pain and trauma symptoms were found to predict the outcome independently, a mediation model was tested to examine whether fear-of-pain mediates the effect of trauma symptoms on pain or uptime.

Standardized coefficients are reported for all level 1 predictors to allow for comparisons of effects. Raw coefficients can be calculated from the standard deviations reported in Table 2. In all results tables the percentage of variance explained is reported in parentheses in comparison to either the empty model (when same hour outcomes are predicted) or the comparison model (in which next hour outcomes are predicted).

The effect of a change in predictor variable on the outcome variable was determined using selected points on the predictor variables and the regression coefficients in which significant predictors were found.

RESULTS

All the participants reported neck pain, 76% reported headache and 45% arm pain as part of their whiplash condition. The mean (SD) NDI score was 45.9 ± 18.8%, a moderate level of disability.[15] The 32 participants completed a total of 546 entries (M = 17, SD = 6.7, range = 8 to 35). The mean number of entries per day was 8.5 out of a possible 10 indicating good compliance of the participants with diary entry. Eleven of these days were on weekends. When entries that were more than 90 minutes earlier the subsequent entry were removed, 452 entries (M = 13.7, SD = 5.3, range = 5 to 27) over 64 monitoring days were retained. Finally, when diary entries without corresponding accelerometer data at preentry and postentry windows were deleted, 329 entries (M = 10.1, SD = 3.9, range = 5 to 19)

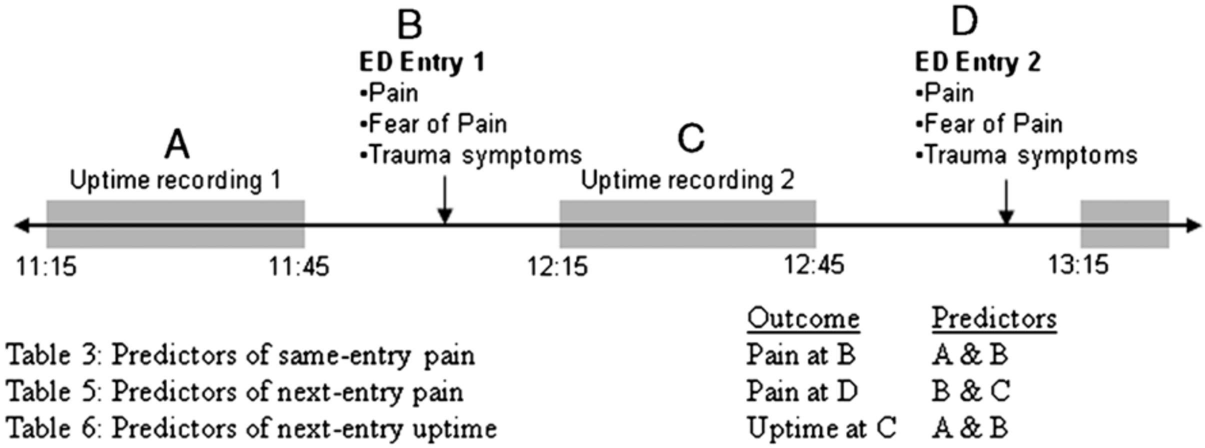

FIGURE 1. Diagram of two sample electronic diary entries illustrating the temporal structure of analyses.

TABLE 3. Predictors of Same-entry Pain

		Trauma				
	Empty	All Scales	Hyperarousal Only	Uptime	Fear of Pain	Hyperarousal and Fear of Pain
Level one						
Intercept	0.374***	0.374***	0.374***	0.374***	0.374***	0.374***
Fear of pain					0.897***	0.887***
Trauma-Intrusion	−0.039ns					
Hyperarousal	0.154**	0.142**			0.031ns	
Avoidance	0.014ns					
Pre-entry uptime			0.054ns			
Variance component						
Intercept	0.050***	0.050 (−0.2)***	0.050 (−0.2)***	0.050 (−0.4)***	0.051 (−1.4)***	0.051 (−1.4)***
Level1	0.014	0.014 (4.26)	0.014 (2.13)	0.014 (3)***	0.009 (37.6)	0.009 (37.6)

Coefficients are standardized; bracketed values represent variance accounted for in the empty model.
$^{**}P < 0.01$; $^{***}P < 0.001$.

over 47 monitoring days were retained. Seven of these days were on weekends. In the final dataset, 19 individuals monitored on only 1 day and 13 for 2 days. See Table 2 for descriptive statistics for the total final data-set (n = 329) and on a per-person (N = 32) basis.

Diary entries took an average of 3.8 minutes to complete (SD = 2.2 min). Ninety-percent of entries were completed in less than 6.7 minutes.

ED Scale Properties

Cronbach's alpha was calculated as a measure of the internal consistency of diary scales, using all diary entries (n = 546). For the fear-of-pain scales $\alpha = 0.95$ and for trauma scales, $\alpha = 0.68$, 0.69 and 0.58 for the intrusion, hyperarousal, and avoidance scales, respectively.

Convergence of Diary Scales With Standard Questionnaires

As a check of the validity of the diary scales, summary scores were compared with standard questionnaires measuring the same constructs. Summary scores were the average of individual's total diary entries. Average pain ratings were correlated $r = 0.75$ ($P < 0.001$) with a single VAS rating of current pain and $r = 0.71$ ($P < .001$) with NDI score. The averaged fear-of-pain scale was related $r = 0.65$ ($P < 0.001$) with the TSK and $r = 0.88$ ($P < 0.001$) with the CSQ Catastrophising scale. Compared with their respective IES-R scales, the diary trauma scales were correlated $r = 0.56$ ($P = 0.002$) for avoidance, $r = 0.73$ ($P < 0.001$) for intrusion, and $r = 0.78$ for hyperarousal. An average of all 3 trauma scales was correlated $r = 0.76$ ($P < 0.001$) with the IES-R Total score.

Prediction of Same-entry Pain

In an initial set of analyses (Table 3) fear-of-pain, trauma (avoidance, hyperarousal, and intrusion), and uptime were entered as separate predictors of same-entry pain. In the empty model 21.9% of total variance in same-hour pain was at the within-person level.

Reports of trauma symptoms in the previous hour accounted for 4.3% of within-person variance in same-entry pain, although only hyperarousal symptoms showed a significant association ($P < 0.01$). Entered alone into a separate analysis, hyperarousal symptoms were associated with increased pain, accounting for 2.1% of within-person variance. Uptime during the preceding 30 minutes period was not significantly related to pain reports ($P > 0.09$). Fear of pain was associated with greater concurrent pain, accounting for 37.6% of within-person variance.

For a nominated 2 or more (out of 5) selected hyperarousal symptoms, same-entry pain will increase by $2 \times 0.142 = 0.28$ units on the VRS, that is 3 feedback anchors. For a nominated change of fear-of-pain of 1 level on the VRS (fear-of-pain), same-entry pain will increase by $0.25 \times 0.897 = 0.22$ units on the VRS (pain) or 2 feedback anchors.

Analyses comparing fixed effects of hyperarousal symptoms and fear-of-pain on same-entry pain reports (the full model) revealed fear-of-pain as the only significant predictor ($P < 0.001$). Both predictors accounted for 36.3% of within-person variance.

A mediation model was formally tested wherein the association between hyperarousal and pain is mediated by fear-of-pain. A significant relationship was found when hyperarousal was regressed on fear-of-pain (Table 4). The sobel test (see www.psych.ku.edu/preacher/sobel/sobel.htm) returned a significant result (coeff. = 3.409, $P = 0.0006$), suggesting that the indirect effect of hyperarousal on pain through fear-of-pain was > 0.

Predicting Pain Across Hours

In the empty model of next-entry pain reports, 22.8% of total variance was at the within-person level (Table 5). Covarying same-entry pain accounted for 13.3% of within-person variance.

After controlling for same-entry pain, fear-of-pain was associated with increased next-entry pain ($P < 0.001$),

TABLE 4. Prediction of Fear-of-pain by Hyperarousal

	Empty	Hyperarousal
Level one		
Intercept	0.221***	0.221***
Trauma-Hyperarousal	0.125**	
Variance component		
Intercept	0.052***	0.052 (0)***
Level1	0.006	0.006 (3.3)

Coefficients are standardized; bracketed values represent variance accounted for in the empty model.
$^{**}P < 0.01$; $^{***}P < 0.001$.

TABLE 5. Predictors of Next-entry Pain Intensity (Controlling for Same-entry Pain Intensity)

	Empty	Comparison	Fear of Pain	Trauma	Uptime	Uptime and Fear of Pain
Level one						
Intercept	0.369***	0.369***	0.369***	0.369***	0.368***	0.368***
Same-hour pain		0.385***	0.199**	0.377***	0.372***	0.194**
Fear of pain			0.432***			0.427***
Trauma-Intrusion				0.048ns		
Hyper-arousal				0.024ns		
Avoidance				0.011ns		
Post-entry uptime					0.099**	0.094**
Variance component						
Intercept	0.0507***	0.051***	0.051 (0)***	0.051 (0)***	0.051 (0)***	0.051 (0)***
Level 1	0.015	0.013	0.012 (7.7)	0.013 (0)	0.013 (3.1)	0.012 (9.2)

Coefficients are standardized; bracketed values represent variance accounted for in the comparison model.
$**P < 0.01$; $***P < 0.001$.

accounting for 7.7% of within-person variance unaccounted for by same-hour pain. No trauma scale was significantly related to next hour pain ($P > 0.12$). Uptime during the intervening half-hour was associated with increased next-hour pain ($P < 0.01$), accounting for 3.9% of within-person variance above that accounted for by same-hour pain. A comparative analysis of the 2 significant predictors (the full model) revealed that fear-of-pain ($P < 0.001$) and uptime ($P > 0.01$) were independently associated with an increase in pain across hours, together accounting for 9.2% of within-person variance after removing the effect of same-hour pain.

For a nominated change of fear of pain of 1 level on the VRS (fear of pain), next-entry pain will increase by $0.25 \times 0.432 = 0.11$ units on the VRS (pain) or 1 feedback anchor. For a nominated increase in uptime of 10 minutes, next entry pain (VRS) will increase by $0.3 \times 0.372 = 0.11$ units on the VRS (pain) or 1 feedback anchor.

Predicting Postentry Uptime

In an empty model, 76.5% of variance in postentry uptime was at the within-person level (Table 6). Change from pre- to postentry accounted for 22.2% of within person variance. Trauma symptoms accounted for 1.7% of within-person variance in preentry to postentry change in uptime. Trauma-related avoidance symptoms was the only significantly predictor, associated with decreased uptime ($P < 0.01$).

For a nominated 2 or more (out of 5) selected trauma avoidance symptoms, postentry uptime will decrease by $2 \times 0.179 = 0.358$ or 10.7 minutes.

DISCUSSION

The results of this study showed that fear-of-pain contributes to both concurrent and next hour levels of reported pain in individuals with chronic WAD. Trauma-related symptoms of hyperarousal also contributed to pain levels across hours. Perhaps surprisingly it was not fear-of-pain but rather trauma related avoidance symptoms that predicted decreased levels of activity (measured in this study as time spent in an upright posture). These findings indicate with-in person relationships between reported pain levels, physiological and physical manifestations of WAD.

Fear-of-pain has been proposed to contribute to the perception of pain[30] and our results support this proposal. On occasions when individuals reported more fear-of-pain they also reported greater concurrent pain. It is unclear whether fear-of-pain contributed to the experience of pain intensity or whether the effect reflects emotional reactivity to pain itself. Cross-hour analyses, conducted to investigate the direction of the effect, supported the notion that fear-of-pain contributes to reported pain, although the effect

TABLE 6. Predictors of Postentry Uptime (Controlling for Preentry Uptime)

	Empty	Comparison	Pain	Trauma	Fear-of-Pain
Level one					
Intercept	0.754***	0.754***	0.754***	0.754***	0.754***
Pre-entry uptime		0.288***	0.284***	0.295***	0.283***
Fear of pain					0.110 ns
Trauma					
Intrusion				0.029 ns	
Hyperarousal				−0.025 ns	
Avoidance				−0.179**	
Pain			0.1142 ns		
Variance component					
Intercept	0.039***	0.040***	0.040 (0)***	0.040 (0)***	0.040 (0)***
Level1	0.082	0.075	0.075 (0)	0.074 (1.72)	0.075 (0)

Coefficients are standardized; bracketed values represent variance accounted for in the comparison model.
$**P < 0.01$; $***P < 0.001$.

was much smaller than in same-entry analyses. In real terms, for a nominated increase in reported fear-of-pain by 1 point on the 5 point ED scale, concurrent pain will by 2 points (on a 12 point scale) and next-hour pain by 1 point. On the basis of previously reported changes in pain levels, our findings are clinically relevant.[31] They also support findings of earlier investigation in conditions such as chronic low back pain[13] but ours is the first study to show using a within-person design that fear-of-pain contributes to the pain reported by individuals with chronic whiplash. It should be noted that our diary measure of fear-of-pain included 2 (out of 6) items of pain catastrophising.

There is growing evidence that physiological trauma is associated with increased experience of pain.[6,7] Trauma may influence pain directly through attention or mood-related mechanisms[7] or indirectly through the development of depression or anxiety sensitivity.[6] Trauma symptomatology after whiplash injury has been shown to be associated with poorer functional recovery[4,25] but effects on pain and activity have not been investigated. We sought to clarify whether a more direct link exists by examining whether trauma symptomatology and pain vary together in daily life.

In our study, hyperarousal symptoms showed a relationship with concurrent pain levels. For a nominated 2 or more (out of 5) selected hyperarousal symptoms, concurrent pain increased by 3 points on the VRS and this could be considered clinically relevant. However this effect was mediated by fear-of-pain. That is physiological arousal associated with thoughts or reminders of the MVC seemed to have an immediate or short term (less than an hour) impact on perceived pain/symptomatology through activation of the fear network. This supports proposals that fear of pain may mediate the relationship between trauma symptomatology and pain perception.[2]

The promotion of activity is advocated for the management of WAD[32] and thus it would seem important to identify processes associated with decreased activity that may be amenable to intervention. While we hypothesised that heightened fear-of-pain would be related to decreased uptime, this was not borne out and it was trauma-related avoidance symptoms that were associated with decreased uptime. There are a number of possible explanations for the lack of effect of fear-of-pain. First, at the chronic stage individuals who are fearful of pain may have reached a "stasis" whereby their fearful beliefs about pain and movement maintain a state of general avoidance of movement,[8,33] exhibiting lower overall activity and fewer activity "events" from which to reactively escape. Providing some support for this, unreported results of the current study found trends for those with high kinesiophobia (TSK >40; $n=15$) to spend less time upright than a low kinesiophobia group (TSK $<=40$; $n=17$), although the effect did not reach statistical significance (mean per-minute uptime $=80.9\%$ vs. 68.6%; $t=1.8$, $P=0.08$).

Second, while we purposively selected the measure of uptime (upright posture) as an activity measure that is clinically relevant for neck pain, other measures of activity (for example general activity or neck movement) may provide different results. Finally, there may be considerations with the time-window used for measurement of uptime. A 30 minutes window commencing up to approximately 28 minutes after diary entries were completed may be of too short a duration, or of too long or short a latency, to show the effect. Although individual patterns of pain, fear, and avoidance are likely to differ, little is currently known about the typical duration and temporal features of these factors and their inter-relationships. This makes it difficult to determine the most effective sampling strategies. Fear may be prompted in anticipation of a feared activity or pain-related cue, in which case avoidance may not occur for some hours. Alternatively, fear may be aroused concurrently with a spontaneously occurring activity, in which case avoidance and fear may occur simultaneously. In such a case, residual fear (such as about delayed-onset pain) may persist once normal patterns of activity have resumed.

The trauma avoidance-symptoms scale was associated with down-time in the half-hour window after diary entries. For a nominated 2 or more (out of 5) selected trauma avoidance symptoms, postentry uptime decreased by 10.7 minutes and this could be argued to be clinically significant. The scale reflects efforts to avoid thoughts, feelings, and situations associated with the MVC that precipitated the WAD, so it is interesting that it was associated with behavioral withdrawal from physical activity. A commonly accepted goal for the management of WAD is to improve or at least maintain activity levels.[31] Thus it would seem important for clinicians to identify trauma symptoms to ensure that all potential hindrances to improve movement/activity levels and restore function are considered. With respect to our measurement of trauma symptoms, it could be argued that frequent sampling may influence the reporting of such symptoms. However t tests conducted on the data at the first and final entries of each day showed no significant change in reported trauma symptoms (all $P>0.209$), indicating stability of these symptoms over the sampling period.

Finally, activity seemed to provoke pain—uptime was related to increased next-hour pain and this effect was independent of the effect of fear-of-pain on next-hour pain. For a nominated increase in uptime of 10 minutes, next entry pain (VRS) increased by 1 point and this is arguably marginally clinically relevant.[31] Nevertheless it suggests that care should be taken with programs which aim to increase activity levels to avoid excessive pain exacerbation and possibly the "boom or bust" cycle commonly seen in chronic musculoskeletal pain conditions.[34]

The effect sizes reported in the current study ranged from moderate (37.6%) to small (1.72%). However, it is well accepted in the area of daily diary research that traditional between-subjects effects are of greater magnitude than within-subject effects.[13,22,35] For example, Sorbi et al[31] reported that momentary pain intensity accounted for 9%, 6% and 1% of within-person variance in the ED-reported outcomes of physical capacity, pain-related interference, and immobility, respectively. By contrast, at the between subject level, pain-intensity accounted for 14%, 35% and 23% of variance, respectively. Furthermore, the proportion of variance explained in cross-lag analyses is consistently smaller than in same-lag analyses,[13,22] especially when controlling for earlier-lag values of next-lag outcomes.[36] Furthermore by using selected cut-off points on predictor variables, we have shown that the changes in outcome variables are in the majority, clinically relevant.

The current study was concerned primarily with within-subject effects, thus the diary-level sample size was of primary concern. Nevertheless, it may be argued that because the majority of participants monitored for only 1 day, and that the majority of days (85%) were week days, results may not be representative of a full range of daily experiences.[37] In addition, because monitoring commenced from 11:00 am the results of the current may not be representative of processes in the early-morning, which may include stiffness and functional impairment in the morning routine.

This research supported the role of fear-of-pain in chronic whiplash—although not in the way expected. Notwithstanding the possibility that the time-window sampled did not detect movement effects and that uptime may not capture the nature of behavioural avoidance in WAD patients, the primary effect of fear-of-pain seemed to be to increase the reporting of pain. The implication of this is that at the chronic stage those with high pain-related fear may benefit from interventions aimed at dampening physiological reactivity to pain and attention to pain, and attenuating fear-producing appraisals of pain. Such interventions, including graded exposure to treat fear-of-pain have been shown to be efficacious in chronic low back pain[38] and investigation of such approaches for chronic whiplash is warranted.

A role for trauma symptomatology in the daily pain experience of WAD was also supported. Specifically, efforts to avoid thoughts, feelings, and situations reminiscent of a traumatic MVC were linked to behavioural withdrawal in the form of reduced uptime. Also, trauma-related hyperarousal seemed to prompt fear-of-pain, which in turn had implications for the pain experience. The physical recovery of chronic WAD patients with significant trauma symptomatology may be promoted by interventions aimed at increasing active means of coping with trauma-related distress and decreasing the tendency to fall back on passive strategies. The current study highlights the need to assess trauma in the context of pain conditions with traumatic onset.

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