Age-related Differences in Pain Recovery after Motor Vehicle Collision: A Prospective Longitudinal Study and Systematic Review of the Prognostic Factors for the Development of Persistent Pain after Motor Vehicle Collision

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Abstract

Background: Persistent pain after motor vehicle collision (MVC) is a major public health problem. There is currently limited literature regarding the recovery of older adults after MVC. This study and concurrent systematic review of the literature aimed to determine whether age is a relevant predictor of persistent pain and if older adults experience less recovery from pain than younger adults during the first six weeks after involvement in a MVC.

Methods: The research portion is an analysis of data from a prospective study of adults presenting to one of eight emergency departments after MVC without fracture or injury requiring admission. Pain severity was evaluated in-person in the emergency department (ED) and by phone six weeks after the collision using a 0-10 scale. Pain recovery was defined as pain score reported during the ED interview minus the average pain score during the past week at the six-week follow-up. The systematic review portion gathered findings and assessed the quality of published literature following MVC-victim cohorts that included adults over 65 years of age.

Results: The analysis showed that patients age 65 years and older had significantly less pain recovery than younger patients (p<.01). The relationship between older age group and reduced pain recovery persisted after adjustment for patient sex, marital status, pre-collision health status, initial pain in the ED, pain in the month prior to the collision, and the severity of vehicle damage (p<0.05). The review revealed that very few good quality studies include adults over 65, and that age and initial pain are strong predictors of persistent pain after MVC-related injury.

Conclusions: Among adults presenting to the ED with moderate or severe pain, older age was associated with reduced pain recovery at six weeks. Further research including older adults and longer follow-up periods is necessary to fully understand the relationship between persistent pain and age after MVC-related injury.
1. Introduction

Chronic pain is a major public health problem among older adults because it diminishes quality of life for affected individuals, is difficult to treat, and is associated with functional decline, falls, and death. (1-4) Motor-vehicle collisions (MVCs) are the second most common cause of injury resulting in emergency department (ED) visits among adults age 65 years and older, and such visits are projected to more than double over the next two decades. (5-8) As with younger adults, most older adults who present to the ED after MVC do not have injuries requiring hospital admission. (9) However, even individuals experiencing MVC not resulting in hospitalization are at risk for persistent pain. Among younger adults, 20-25% experience persistent MVC-related pain six months after the collision. (10) The economic cost of MVC-related pain is estimated to be $29 billion per year in the US alone. (10-14) Persistent MVC-related pain is a physical, emotional and financial burden for patients of all ages.

Although the incidence of persistent pain after MVC in older adults has not been well characterized, advanced age appears to be a risk factor for persistent pain after MVC. (13-18) Further evidence that older adults may be less likely to recover from acute pain conditions comes from studies of back pain and experimentally-induced pain. (19-22) Understanding whether and to what degree older adults are at increased risk for persistent pain and what factors might contribute to this elevated risk is an important step in improving outcomes for older adults experiencing MVCs.

The objective of this study was to examine changes in pain severity during the early recovery period after MVC across the lifespan. We hypothesized that among individuals
presenting to the ED with moderate or severe pain due to MVC, the decrease in pain severity during the first six weeks after the injury would be less for patients age 65 years or older than for younger patients.

2. Methods

We analyzed data from a prospective longitudinal study of adults recruited from eight emergency departments in four “no fault” insurance states (Michigan, Massachusetts, New York and Florida) between February 2009 and December 2012. The study was approved by the institutional review boards of all participating hospitals, and each participant provided written informed consent. Study participants were enrolled and received initial post-MVC interview evaluation at the time of the ED visit, and follow-up assessment was performed at six weeks. Additional details of the methods have been published separately. (23)

2.1 Participants

Patients who presented to the ED within 24 hours of a minor MVC with injuries unlikely to require admission were screened for eligibility. Because the study was primarily designed to examine the relationship between genetic characteristics and the development of persistent pain, and in order to avoid population stratification bias, enrollment was limited to non-Hispanic white adults. Patients with fractures, intracranial injury, laceration with significant hemorrhage, or other injury or condition considered life-threatening or likely to require hospital admission were excluded. Patients who were enrolled because they were not known to have fractures but were diagnosed with one or more fractures during the ED evaluation were also excluded from these analyses. Patients age 65 and older with moderate or severe cognitive impairment were excluded. Cognitive impairment was not formally assessed in younger patients, but all patients had to
demonstrate the capacity for informed consent. Among enrolled participants, two additional criteria were applied to restrict the current study sample. Patients were excluded if they had mild or no pain (pain score of 3 or less) or if they reported hiring an attorney in relation to the MVC at the time of six-week follow-up. The latter criterion was employed for this study in order to minimize the effect of compensation on pain outcomes. (24, 25)

2.2 Measures

Emergency department interviews were conducted by trained research assistants using standardized questionnaires with explicit definitions of study variables. Follow-up surveys were conducted at six weeks after the MVC either over the phone, by mail, or online. Participants were monetarily compensated for ED interviews and for each follow-up assessment. Pain severity was assessed using a 0 to 10 numeric rating scale. Consistent with previously established cut-points and clinical practice, moderate or severe pain was defined as a pain score greater than or equal to 4. (26, 27) Average pain in the month preceding the MVC was determined by patient report on the same scale. Overall health status was established by self-reported rating of pre-collision health as poor, fair, good, very good, or excellent. Collision characteristics were obtained from the patient during the ED interview. (28) The severity of motor vehicle damage was rated by the patient as being minor, moderate, or severe, with the latter defined as the vehicle not being drivable. At six-week follow-up, pain severity rating was determined as self-reported average pain during the past week on the numeric scale.
2.3 Statistical Analysis

Pain recovery was defined as the pain score reported during the ED interview minus the average pain score during the past week at the six-week follow-up interview. Age groups for analyses were defined as follows: 18 to 39 years, 40 to 64 years, and 65 years and older. Multiple categories were chosen in order to allow for the possibility of a non-linear relationship between age and pain recovery. Analysis of variance was used to compare pain and pain recovery by age group. Multivariable regression was used to determine the relationship between age group (treated as a categorical variable) and pain recovery adjusted for patient sex, marital status, pain in the ED, average pain in the month preceding the MVC, overall pre-collision health status, and extent of vehicle damage. Pain in the past month, initial ED pain intensity, overall health status, and extent of vehicle damage were treated as continuous variables for these analyses. The final multivariable linear regression model was used to estimate mean recovery scores for each age group adjusted at the mean value of covariates with p-values reflecting overall significance of the relationship. All available data meeting the above-stated eligibility criteria were used for analyses, and no sample size calculation was performed. Analyses were conducted using Stata IC 11.0 (StataCorp LP, College Station, Texas).

3. Results

3.1 Participant characteristics

A total of 1,013 European American patients consented to study participation and completed the ED evaluation; these patients formed the original study sample. Participants who were non-white (n=12), hiring an attorney at six-week follow-up (n=206), or had no pain or mild
pain at the initial ED visit (n=203) and/or missing 6 week pain data (n=91) were excluded from analysis.

Patient and collision characteristics by age group of the final sample are described in Table 1. Of the 534 patients in the study sample, approximately two-thirds were female in each of the three age groups (Table 1). Patients in each of the age groups were also similar in regard to the proportion who were drivers and the proportion reporting moderate or severe vehicle damage. A greater proportion of patients in the oldest age group were married, had no formal education beyond high school, or had moderate or severe pain in the past month. However, the majority of patients in all age groups reported no pain or mild pain in the month preceding the MVC. Overall health status was generally reported as good or above in all three age groups, although older patients tended to report being in excellent pre-collision health less than the younger groups. Follow-up was obtained for 88% of all patients with moderate or severe pain in the ED and was similar for each of the age groups: age 18-39=85%; 40-64=93%; ≥65=97%.

3.2 Bivariate and Multivariable Analyses

In unadjusted analyses, both mean ED pain severity and follow-up severity were statistically similar for the three age groups (Table 2). However, the crude pain recovery, defined as ED pain minus six-week pain severity, was significantly different among the three age groups with older adults experiencing less pain recovery than patients in the two younger age groups (p<0.01). Six weeks after the MVC, 39% of older adults reported an average pain score less than or equal to 3 during the past week. Histograms of initial pain in the ED and at six weeks post-injury illustrate the distribution of pain scores and flattening of the normal curve from initial visit to follow up, which represents the degree of recovery (Figure 1). After adjusting for sex, marital status, overall health status, pain in the ED, average pain in the month before the MVC, and the
severity of vehicle damage, pain recovery remained significantly less for older adults compared with that of the younger age groups (p<0.05)(Table 2).

4. Discussion

In this prospective study of pain recovery during the first six weeks after MVC, we observed a significant association between age group and pain recovery, with adults age 65 or older experiencing less pain recovery than younger age groups. The relationship remained significant after adjusting for other patient and collision characteristics, which might confound the relationship between age and pain recovery. (29) These results add to existing evidence that older age is a risk factor for the transition from acute to persistent pain after MVC and possibly other forms or acute injury. These findings highlight the need for additional understanding of the mechanisms underlying the persistence of pain after MVC in older adults and the development of interventions to prevent this outcome.

Overall, existing evidence supports the claim for age-related persistent pain development. A few recent studies are available describing an association between age and progression to persistent pain after serious injury, which included elderly patients in analyses. Large international trials of adults of all ages have identified advanced age as a strong predictor of chronic pain. (30, 31) A large cross-sectional epidemiological survey study conducted in Sweden describes an increasing gradient for chronic regional pain by age, noting that patients age 59-74 years were at the highest risk. (32) Other population-based international evidence also points to older age as a determining factor in the presence of persistent pain. (33, 34) Although a few older studies reported a peak in chronic pain prevalence in middle age or a plateau in pain intensity after 70 years of age, no longitudinal findings have been expressed in terms of pain recovery after mild injury. (35, 36) Pain recovery is an important step in persistent pain stemming from a
specific traumatic impetus like MVC. If an acute injury causes pain, our findings suggest that older adults are more likely than adults of all other ages to develop persistent pain following the insult.

4.1 Clinical and psychological explanations for age-related differences in pain recovery

Age-related psychological differences in coping mechanisms have been cited as a potential explanation for variations in pain experiences across age groups. According to a large Norwegian study, older adults reported more chronic pain but tended to have higher total quality of life scores, greater satisfaction with life, and better moods compared to other adult age groups. Similar studies have found that older patients reported less distress, but had pain of longer duration than other ages. (These findings suggest that age-related differences in the prevalence of chronic pain exist, but the psychological sequelae may be less bothersome in older adults. The most cited explanation for the variance in concern over persistent pain by age is that older adults cope by accepting pain as a part of the normal aging process. Beyond the acceptance of pain as a burden of older age, some research supports the idea that older adults tend to be more stoic in reporting pain symptoms, making pain intensity scores from this age-group under-representative of actual pain experience. This potential under-reporting of pain is supported by lower mean ED pain scores for older adults in the current study. One possible consequence of both explanations for older adults reporting lower initial pain scores after injury is that this group is subsequently medically under-treated, leading to a higher likelihood of persistent pain. The current study attempts to correct for potential under-reporting in two ways. First, by analyzing pain scores from patients reporting only moderate to severe pain at the initial ED visit, it is more likely that the patient reports coincide with actual pain experience. Second, this study focuses on pain recovery, not simply pain intensity, in order to counteract the effects of under-
reporting and still illustrates significantly less recovery for older adults. The available literature suggests that the experience of persistent pain is more common but may be reported differently in older adults, and the current study attempts to avoid the pitfalls of possible psychological variations in pain score reporting by older adults by assessing pain recovery in patients with initially high pain intensity after MVC.

Existing clinical evidence suggests that functional decline as a byproduct of injury may mediate the development of persistent pain in all age groups. With this functional decline being relatively greater in older adults, persistent pain is also more likely in this age group following injury. (3, 43) Most reports of loss of function after injury focus on working-age adults, and tend to show that middle-aged, female patients suffer functional decline and increased rates of persistent pain. (44) In a study designed to assess the functional decline of older adults one month after minor injury not requiring hospitalization, Wilber et al found that 35% of patients had continued functional decline. (45) Other research specifically points to musculoskeletal pain, especially pain in several locations, as a predictor of mobility disability in community-dwelling older adults. (46) A pilot study conducted by the author highlights the negative effects of pain on functional ability in patients over 65 years of age, finding 48% of participants had pain interference with general activity at six weeks post-MVC. (18) Evidence also suggests that pain diminishes functional status with increased age, even if pain intensity remains the same. (47) If functional decline affects pain recovery trajectories and minor injuries cause greater disability in the older adult population, then the reduced rates of pain recovery seen in the current study would be expected.
4.2 Experimental evidence for age-related differences in pain recovery

Compelling experimental evidence indicates that age-associated changes in nociceptive perception may help explain the increased prevalence of persistent pain with advancing age. Older adults may have a diminished ability to respond to the stress of persistent pain, or “pain homeostenosis,” which results in reduced pain recovery. (48) Evidence suggests that older adults have age-associated changes in pain processing, with an inability to down-regulate sensitization. (48, 49) According to one recent study, healthy older adults exhibit decreased pain modulation capacity when compared to younger adults, meaning that older patients were unable to demonstrate pain reduction with administration of a pain-conditioning stimulus. (50) The authors hypothesize that these age-specific differences are related to reductions in neurotransmitters that modulate pain, as demonstrated in animal models, or to the diminished release of B-endorphin, a stress and pain mediator, with advanced age. Work by Riley et al. supports that older adult patients reported lingering pain more often than younger adults. (50) This reduced pain recovery may be secondary to a hyper-excitible neuronal axis that prolongs the resolution of pain in older patients, or to the observed decreased inhibition with conditioned pain modulation. (50) Consistent with the results of the current study, if older adults are less able to modulate pain, then recovery after acute injury would be diminished and older patients, at minimum, show delayed recovery and may be more likely to develop persistent pain.

4.3 Strengths and limitations

We are unaware of any previous studies that have prospectively assessed the persistence of pain after MVC across the entire lifespan. A review of the prognostic factors for persistent pain following acute orthopedic trauma was recently published, which noted that several high quality studies showed a strong association between age and the development of chronic pain;
however, all the studies limited the age of participants to working-age (i.e. less than 70 years old). (29, 51) Previous research on persistent pain did not assess pain intensity at early recovery intervals, which is necessary to characterize the trajectory of persistent pain over time. (52, 53) Furthermore, evidence from several sources indicates that the initial weeks after MVC may constitute a critical period of plasticity, after which pain trajectories are relatively fixed. (54-56) Large scale longitudinal studies of acute musculoskeletal pain conditions indicate that recovery or persistence is determined in most patients in the first four weeks. (54-56) Similarly, although the timing of recovery after MVC is less well studied, existing work points to the first month as a critical time in which patients either recover or develop persistent pain. (10, 14) This study specifically addresses pain recovery over the six weeks directly following the MVC, which will allow for comparisons with other time points in the longitudinal follow-up period.

The multivariate analysis was carefully conducted after assessing the level of association of each potential confounder, determined from extensive review of the literature regarding predictors of persistent pain. Gender was adjusted for in the final model, as strong evidence for an increased likelihood of the development of chronic pain in women compared to men has been extensively validated. (29, 57) Another covariate, marital status, was associated with age in our cohort, with many older adults being married. This adjustment is also supported by literature that ties a lack of social support increased risk for the development of persistent pain. (58) High initial pain intensity post-injury has been shown in a number of studies to be a strong predictor of continued pain and was controlled in the final model. (30, 51, 59) Overall health status is controlled in the final model as baseline poor health may influence the rate of recovery. Finally, extent of damage to the vehicle was justifiably controlled in this model as a surrogate for injury severity, a moderate predictor of pain outcomes. (29) This study has analytical strength in a
multivariate analysis of longitudinal, prospective data collected over a prolonged period of time in a large, multi-generational cohort.

The current study has several limitations. Only half of patients eligible for enrollment consented to study, therefore it is unclear if the results are generalizable to all adults. Among eligible patients, reasons for non-participation were similar for younger and older adults, with the most common reasons given being concerns regarding the amount of time needed to complete the interview. We only included Caucasian patients in our analysis. Other racial and ethnic groups may have higher rates of persistent pain, and the relationship between age and pain recovery may also differ for other racial and ethnic groups. (60) We defined older adult as those age 65 years or older because this is a commonly used cut point but not necessarily the optimal one for understanding the relationship between age and pain recovery. A larger sample of older adults would allow a more granular examination of the relationship between age and pain recovery and would also allow greater precision of estimates. Emergency providers likely have a lower threshold for admitting older patients who experience MVC than for admitting younger MVC patients, but patients themselves have the ability to influence admission decisions. Age-related differences in admission thresholds after MVC might have introduced selection bias into the study, although this would presumably enrich the older group with patients with less severe injuries or more resilience as judged by either the physician or the patient.

Because we were interested in pain recovery, we included only patients reporting pain severity scores that were moderate to severe at the initial ED visit. The reasoning behind the exclusion was that pain severity close to zero at the onset would show limited amount of recovery by necessity. This means that some patients that under-reported initial pain, or that had borderline moderate pain in the ED were not included in the analysis.
There are a number of factors that might confound the observed association between age group and pain recovery that were not included in this analysis. Although the benefit of conventional therapies appears to be small, medical treatment in the emergency department and during the first six weeks might influence the transition from acute to persistent pain and might have differed by age group. (29, 30, 53) Finally, although pain trajectories after MVC are relatively stable by six weeks, a proper understanding of the progression of persistent pain after MVC would require follow-up over a longer time period. (10, 14)

5. Conclusion

Persistent pain is a costly, debilitating problem for adults of all ages, but poses a significantly increased risk to the health and functioning of older adults. (47, 61) Our findings suggest that for adult patients of all ages experiencing MVC, the recovery from pain related to the MVC after six weeks is significantly less for adults over 65 years of age, after adjusting for important potential confounders. This has important practice implications as these patients may require more frequent physician involvement, psychological treatment, or rehabilitation after minor injuries to prevent the development of persistent pain. With a demographic shift towards increased numbers of older adults in the patient population, the issue of differences in pain recovery after injury is critical for determining appropriate treatment methods and avoiding poor long-term pain outcomes.
Table 1. Characteristics of the study sample, by age group.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>18-39 (n=325)</th>
<th>40-64 (n=173)</th>
<th>≥65 (n=36)</th>
<th>18-99 (n=534)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age, mean (SD), y</strong></td>
<td>26 (6.1)</td>
<td>50 (7.4)</td>
<td>70 (5.6)</td>
<td>37 (15.6)</td>
</tr>
<tr>
<td><strong>Female</strong></td>
<td>66</td>
<td>67</td>
<td>64</td>
<td>66</td>
</tr>
<tr>
<td><strong>Marital Status</strong></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Married</td>
<td>27</td>
<td>59</td>
<td>69</td>
<td>40</td>
</tr>
<tr>
<td>Unmarried</td>
<td>73</td>
<td>41</td>
<td>31</td>
<td>60</td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-11 years</td>
<td>4</td>
<td>5</td>
<td>17</td>
<td>5</td>
</tr>
<tr>
<td>High School</td>
<td>17</td>
<td>23</td>
<td>26</td>
<td>19</td>
</tr>
<tr>
<td>Post-High School(^a)</td>
<td>46</td>
<td>30</td>
<td>31</td>
<td>40</td>
</tr>
<tr>
<td>College Graduate</td>
<td>24</td>
<td>24</td>
<td>14</td>
<td>24</td>
</tr>
<tr>
<td>Post Graduate</td>
<td>8</td>
<td>17</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td><strong>Driver</strong></td>
<td>85</td>
<td>91</td>
<td>89</td>
<td>87</td>
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<td><strong>Smoker</strong></td>
<td>32</td>
<td>21</td>
<td>6</td>
<td>27</td>
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<tr>
<td><strong>Drinks &gt;3 per week</strong></td>
<td>46</td>
<td>35</td>
<td>33</td>
<td>42</td>
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<tr>
<td><strong>Severe life threat(^b)</strong></td>
<td>27</td>
<td>29</td>
<td>33</td>
<td>29</td>
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<tr>
<td><strong>Car Damage Severity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor</td>
<td>11</td>
<td>14</td>
<td>3</td>
<td>12</td>
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<tr>
<td>Moderate</td>
<td>28</td>
<td>35</td>
<td>30</td>
<td>30</td>
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<tr>
<td>Severe</td>
<td>61</td>
<td>51</td>
<td>67</td>
<td>58</td>
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<tr>
<td><strong>Average pain past month</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>None (pain score = 0)</td>
<td>69</td>
<td>53</td>
<td>42</td>
<td>62</td>
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<tr>
<td>Mild (1-3)</td>
<td>11</td>
<td>21</td>
<td>31</td>
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<td>Moderate (4-6)</td>
<td>12</td>
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<td>17</td>
<td>13</td>
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<td>Severe (7-10)</td>
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<td>10</td>
<td>11</td>
<td>9</td>
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<tr>
<td><strong>Overall Health</strong></td>
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<tr>
<td>Poor</td>
<td>1</td>
<td>1</td>
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<td>Fair</td>
<td>6</td>
<td>10</td>
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<td>Good</td>
<td>19</td>
<td>25</td>
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<tr>
<td>Very Good</td>
<td>44</td>
<td>39</td>
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<tr>
<td>Excellent</td>
<td>30</td>
<td>25</td>
<td>19</td>
<td>28</td>
</tr>
</tbody>
</table>

\(^a\) Either technical school or some college.

\(^b\) Rate of threat to life from MVC described by patient as >7 (0-10 scale).

\(^c\) MVC fault per the patient
Table 2. Pain in the emergency department and pain recovery 6-weeks after motor vehicle collision, by age category.

<table>
<thead>
<tr>
<th>Age Group (years)</th>
<th>ED pain</th>
<th>6-week pain(^a)</th>
<th>Pain Recovery(^b)</th>
<th>Adj. Pain Recovery(^c)</th>
<th>% Mild Pain at 6 weeks(^d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-39</td>
<td>6.4</td>
<td>3.5</td>
<td>2.9</td>
<td>2.9</td>
<td>53</td>
</tr>
<tr>
<td>40-64</td>
<td>6.2</td>
<td>4.0</td>
<td>2.2</td>
<td>2.2</td>
<td>44</td>
</tr>
<tr>
<td>≥65</td>
<td>6.0</td>
<td>4.0</td>
<td>1.9</td>
<td>2.0</td>
<td>39</td>
</tr>
<tr>
<td>P value(^e)</td>
<td>0.237</td>
<td>0.101</td>
<td>0.008</td>
<td>0.020</td>
<td>0.084</td>
</tr>
</tbody>
</table>

\(^a\) Defined as average pain in past 24 hours at time of 6-week assessment, range 0-10.

\(^b\) Defined as pain score on arrival to the emergency department minus average pain during past 24 hours at 6 week assessment.

\(^c\) Adjusted for gender, extent of damage, marital status, pain in ED, overall health status prior to the accident, and past pain. Larger number indicates greater decrease in pain.

\(^d\) Percent of patients with zero to mild (pain score ≤3) pain at 6 weeks post-MVC

\(^e\) Analysis of variance or Pearson’s chi-squared test
Figure 1. ED pain scores and 6 week pain by each age group with normal curves
Systematic Review of the Prognostic Factors for the Development of Persistent Pain after Motor Vehicle Collision

1. Introduction

Adult persistent pain is currently recognized as an international public health problem. A recent global report estimates that nearly 1.5 billion people suffer from persistent pain worldwide, with an estimated 100 million sufferers in the United States alone. (62, 63) According to an Institute of Medicine Report, persistent pain is a public health problem that costs an estimated $560-$635 billion annually, the equivalent of $2,000.00 per person living in the U.S. Lost productivity due to diminished functional status and wages accounts for nearly $300 billion, the majority of the total expense. (64) Nine in ten pain sufferers have visited at least one medical professional, placing a substantial burden on the medical system. (65) Persistent pain is not only a significant source of economic cost and functional disability; it also has strong associations with the development of anxiety, depression, and medication misuse. (63, 64) A 2006 American Pain Foundation survey found that 77% of chronic pain sufferers endorsed feeling depressed. (63) Persistent pain, clearly presents an important multi-faceted challenge for medical professionals and enhanced understanding of the factors that predict this adverse outcome could lead to earlier intervention.

Though the majority of persistent pain is attributable to chronic painful conditions, such as osteoarthritis, painful acute injuries are also an important impetus for the development of chronicity. (10, 63) Motor-vehicle collisions are important causes of persistent pain symptoms. (66) There is evidence to support risk factors for the development of chronic pain following these types of physical injuries, however most reviews have been limited to studies including patients
less than 65 years of age. (67, 68) An increasing number of older adults are active and driving, which has led to a rise in the amount of accidental injuries involving this population. (66, 67) In older adults, persistent pain has been associated with functional impairment, decreased balance, falls, and mortality, making efforts to characterize and prevent the development of ongoing pain in this growing population a particularly important challenge. (1, 10, 18, 62, 69) Despite the projected exponential growth in the number of older drivers and the evidence suggesting variations in age-related pain experiences, little is known about the differences in pain recovery outcomes after MVC-related injury across the lifespan.

One challenge facing physicians of patients suffering acute traumatic injury of any degree of severity is predicting the prognosis for recovery. Predictors of the prognosis for pain recovery after injury are likely to be related to the type of injury and to the patient’s unique biopsychosocial features. (58, 70) Some often cited predictors purported to be associated with adverse recovery outcomes are older age, female gender, lack of social support, pre-injury depression or anxiety, lower educational level, and smoking, although these claims are generally inconsistent or not generalizable to a broader range of patient’s suffering acute injury. (14, 68, 71-74) For example, previous reviews have focused on specific major trauma types, like spinal cord injury or traumatic brain injury, or failed to account for multiple injury sites. (25, 75, 76) Other reviews on the topic have reported outcomes, like pain-related functional status, limiting consistent evidence for the predictors of persistent pain specifically. (75, 77) Importantly, older age has been inconsistently linked with an elevated risk of persistent pain after injury; however, very few studies have actually included drivers older than 65 years of age. (68) A synthesis of the available research evidence on the factors associated with the development of persistent pain outcomes after acute injury due to MVC is warranted as it may facilitate the earlier identification
of at-risk patients and the development of tailored interventions to curb the onset of persistent pain.

With inconsistent reporting of the development of persistent pain in much of the literature, the current systematic review is necessary to build a foundation for clinicians to predict and mediate the outcomes of patients suffering acute accidental injury by motor vehicle collision, especially with regards to differences in pain experience by older adults. The purpose of this review is to identify the prognostic indicators of the development of chronic pain after road-related accidental injury in adults of all ages. This review will focus on studies that report characteristics of driving-age patients experiencing injury by MVC, including the elderly population. Studies will be limited to cohort studies that specifically look at pain outcomes longer than six weeks post-injury. By characterizing the important factors for the prediction of persistent pain after MVC-related injury, future research can control for indicators and clinicians can apply the knowledge to the management of acutely injured patients to prevent the trajectory from acute to chronic pain.

2. Methods

2.1 Search Strategy

An extensive electronic search of the literature on PubMed/MedLine was conducted using MeSH terms "Accidents, Traffic" AND "Pain" AND "Follow-Up Studies," limiting the search results to works published since 1995 with full text available in English. Articles were limited to those published after 1995 because the majority of MVC-related injury research involves whiplash-associated disorders, for which the Quebec Task Force released a formal definition in 1995. (12, 78) Further searches were conducted using the same keywords on
GoogleScholar. Related citations from each of the articles and a secondary search within the reference lists of these studies was also conducted.

2.2 Selection criteria

Articles were included for further review if the following criteria were met:

1) Pain was measured as a main outcome of the study. Pain was assessed at baseline within 1 month of injury and as an endpoint with a valid pain scale measure or dichotomous question, not by simple improvement affirmations.

2) The follow-up pain measure must have been completed at a minimum of 6 weeks after injury, but not longer than two years. The timeline for the detection of chronic pain is somewhat controversial, however a period of at least 6 weeks is generally considered adequate for appropriate healing. (79) Follow-up over two years after injury makes the association with the MVC difficult.

3) Pain must be associated with the injury, and not classified as chronic pain syndrome/chronic widespread pain syndrome/fibromyalgia. Studies that were not specifically focused on the presence of pain post-MVC injury, that focused on treatments or other interventions, or that sought to examine only functional or disability outcomes in the presence of pain, were excluded.

4) The study was a longitudinal (retrospective or prospective) cohort design (no minimum size), and sought to determine prognostic factors related to MVC-related pain recovery.

5) The study included only driving-age, adult patients (over 14), no childhood cohorts were included. In several foreign countries, driving age is less than 16 and studies of the sort were therefore included.
6) Injuries that were MVC-related were likely to be classified as whiplash. Injuries were excluded if classified as burns, acute back pain not related to specific injury, traumatic brain injury, amputation, or surgically-induced wounds. All of these types of injuries have been extensively reviewed in previous works. (29) Accident-related, acute injuries, not caused by the presence of disease, were defined as those that involved the musculoskeletal system, excluding the specific types mentioned above.

7) The study must explicitly include patients over 65 years of age. Many cohort studies of pain do not include the geriatric population, and this information is important to determine if age is a predictive factor. Some research states only mean ages, age over a specific number (i.e. age over 45), or no age range. For the purposes of this review, these were excluded, as the focus on older adult recovery would be impossible if older adults were not specifically included and reported.

All studies not meeting these criteria, or found to be duplicates, as determined by an independent reviewer examining the full text, were excluded (Figure 1). Several studies reported data from the same cohort, which would lead to excessively weighting the prognostic factors included in that data. For the current review, it was decided that extraction of data would be conducted for each cohort only once. The decision of which paper to include was made based on two criteria 1) the first published and/or 2) the main outcome was pain intensity at follow-up.

2.3 Quality assessment

A set of quality criteria previously developed for the systematic review of research on prognostic indicators of musculoskeletal disorders by Hudak et al and a tool to discriminate the quality of the articles on the prognostic factors of whiplash-associated disorders by Scholten-Peeters et al were referenced to develop the combined, modified quality assessment form used in
The final tool used is a quality framework based on 18 items from the following general categories: sampling/study population, methodology, statistical analysis, prognostic factors, and results. The items were determined to be present, not present, or unclear, with an affirmative answer reached in the case of adequate information supplied. Based on the cumulative answers and risk of bias, as determined by the reviewer, the studies were deemed good, fair, or poor quality.

2.4 Data items

A standardized form was developed for the extraction of data from each study and presented in Appendix B. Information regarding the source population, sample size, inclusion/exclusion criteria, prognostic factors, pain measures, follow-up period, univariate outcomes, and multivariate findings was collected from each study by an independent reviewer.

2.5 Strength of evidence

The strength of evidence regarding each prognostic factor was judged based on the findings from each study as strong, moderate, or unclear. Findings from poor quality studies were not considered in determining strength of evidence for a predictor. If more than one fair to good quality study reported significant findings for the same prognostic factor, the factor was labeled as having sufficient (strong) strength of evidence, as determined by the reviewer.
3. Results

3.1 Compiled Study characteristics

Database searching based on search terms and review of reference lists revealed 89 articles. From these potentially relevant studies, 47 met cursory subject criteria related to post-MVC pain outcomes and were further explored as either abstracts or full text. Most of the exclusion (n=20) of otherwise suitable research for review was based on either exclusion of or failure to account for patients over 65 years of age. Four studies were included in the final review. Figure 1 details the inclusion and exclusion of studies and the bases for exclusion.

The main characteristics of the included studies are detailed in Table 1, as well as the rating of quality of the individual studies. The cohorts of all but one study were recruited by either databases and subsequent mail or referral and mail. Only the article by Gun et al in Australia used physicians to recruit patients in the emergency department. (81) The sample sizes varied from 147 to 765 with the average number of patients being 511. Follow-up periods ranged from 1 month to 24 months, however only findings reported after 6 weeks were considered in this review. None of the studies were conducted inside the United States, and all occurred in countries with universal health care systems.

The number of predictive factors examined ranged from 10 to 28, with a large amount of heterogeneity between studies for inclusion, definitions, and measurement of predictors. Prognostic factors determined to be significant predictors of persistent pain in any of the studies were 1) age, 2) gender, 3) psychological distress post-injury, 4) injury severity score, 5) pre-MVC widespread pain, 6) whiplash symptoms post-injury, 7) height, 8) BMI, 9) past whiplash-associated disorder, 10) involvement in litigation, and 11) bodily pain after MVC. (24) All four studies reported significant findings only for age as a predictor of persistent pain. Each factor
and the level of evidence for its predictive capacity for pain at follow-up, based on the number of significant findings for that factor in fair or good quality studies, are detailed in Table 2.

### 3.2.1 Kasch et al (82)

An assessment of the factors that predict long-term pain after MVC-related injury in Denmark by Kasch et al followed a prospective cohort, 18-70 years of age, in rear or front-end collisions with whiplash symptoms for a total of 12 months. (82) Emergency department and primary care physicians referred 688 patients with whiplash injury to the study. Frequency and intensity of neck pain based on a visual analog scale were assessed at each follow-up point. Non-participants were found to be similar to participants and the drop out rate was low. This study was found to be at low risk for bias and of good quality based on the pre-determined criteria. The results of multivariate analysis found age, gender, and severe initial neck pain to be significantly associated with persistent pain.

### 3.2.2 Atherton et al (83)

The study by Atherton et al conducted in the United Kingdom recruited patients aged 17-70 (actual max age was 68) years of age with neck pain after MVC. (83) The 765 patient prospective cohort was followed through mailed questionnaires at 1, 3, and 12 months with the primary endpoint being persistent neck pain. Persistent pain was measured with a question ascertaining whether pain was experienced for one day or more in the week prior. Non-responders, 51% of eligible participants, were not significantly different at baseline. The attrition rate of the study was high at 37% by 12 months post-injury, but drop-outs also did not differ significantly from those that completed follow-up. The results of multivariable models showed that age, psychological distress, widespread pain prior to collision, and being in a vehicle other
than a car at the time of MVC were significantly associated with a doubling of the risk of persistent pain at 12 months. 27% of participants had persistent neck pain at final follow-up questioning. Weaknesses of this study included a low participation rate, high attrition rate, and a high rate of participants pursuing compensation that, in turn, had an increased likelihood to report pain. The study by Atherton et al was found to be of fair quality primarily because of these limitations. (71)

3.2.3 Brison et al (84)

Brison et al conducted a prospective study of victims (age 18-70) of rear-end MVCs in Canada with recruitment through a computerized injury database and subsequent letter. (84) Follow up was conducted at 1, 2, 3, 6, 9, 12, 18, and 24 months through mailed questionnaires. Participation rates were high (93% of eligible patients), and 61% of subjects had neck pain at initial interview. The percentage experiencing neck pain was reduced to approximately 36% by 3, 6, 12, and 24 months post-injury. Risk ratios were reported for predictors with age, gender, height, BMI, and neck pain at initial contact being significantly associated with persistent neck pain at six months post-injury. A multivariate model, appropriate adjustment for confounders such as seeking compensation for the crash, or description of drop-outs versus patients with full follow-up was not demonstrated, making the study quality fair.

3.2.4 Gun et al (81)

A prospective cohort trial in Australia by Gun et al focused on emergency department patients post-MVC by recruiting through emergency physicians. (81) The sample contained only 146 patients, with an age range of 14.1 to 77.9, and patients were followed by mail questionnaire at 12 months. The study resulted in the identification of age, gender, and seeking legal
compensation as predictive factors for persistent pain. The total number of patients with persistent pain at 12 months was not explicitly reported. There were more refusers than participants, and this group was not examined against the participants for similarities or differences. Importantly, 93% of those initially interviewed completed follow-up at the end of the study. Nevertheless, selection bias for participants and the recruitment technique for this small cohort made its quality rating fair.

### 3.3 Persistence of pain

In all four cohorts, persistent pain was common after MVC-related injury. Persistence of pain was reported as a percent of the total cohort experiencing pain at follow-up in three of the four studies. (The percentage of patients in pain ranged from 27 to 40% at the time of follow-up (Table 1). (71, 82, 84)

### 3.4 Strength of predictive factors

Because the research regarding MVC-related injury outcomes often involves heterogeneous potential predictive factors, only those that showed significance in several of these studies was considered sufficiently associated with persistent pain (Table 2). Based on the results of the four studies examined in this review, age and high initial pain intensity after MVC-related injury were the only factors clearly shown to be prognostic of pain outcome at follow-up (Table 2). Older age was invariably linked to greater risk of pain at follow-up, although each study defined the oldest age group differently. Female gender was moderately predictive of persistent pain, as was initial psychological distress. All other significant factors were unclearly associated with persistent pain, either by virtue of non-significant results in several studies or because only one study focused on the factor (i.e. being in a vehicle other than a car at the time
of MVC). Some indicators had mixed results, but overall patient demographic characteristics tended to be more predictive of persistent pain than collision characteristics or prior history of pain.

4. Discussion

Persistent pain after motor vehicle collisions is a costly and important public health problem. According to the results of this review, persistent pain after MVC is common. Between 27 and 40% of patients involved in a collision continued to report pain at follow-up of 3 to 24 months post-injury. This systematic review of the cohorts including older patients regarding prognostic factors for the development of persistent pain after MVC illustrates the lack of consensus and evidence for many potential predictors. However, the studies examined showed consistently that age and intensity of pain at initial evaluation were prognostic of the persistence of pain.

A definitive set of prognostic factors has not been determined, although a review conducted by Walton et al on the risk factors for persistent problems after MVC-related whiplash injury provides a set of variables that were strongly substantiated in cohorts that included initial pain intensity, education, headache, and whiplash grading. (68) Moderate significance was reported for pain catastrophizing, neck pain at initial interview, past history of neck pain, seatbelt use at time of incident, and female gender. Similar to the findings of this review, high initial pain intensity was the strongest predictor after meta-analysis. High initial pain intensity is an apparently useful predictor, which could be used by ED physicians to stratify patients at increased risk for persistent pain in the future.

One potential issue with pain intensity as a risk factor is that there is a potential for selection bias based on other factors in concordance with the pain. Namely, if some patients are
seen as more frail (i.e. females, older patients), the physician could decide that the patient needs to be admitted and would be missed by ED enrollment studies and any recruitment that occurs based on ED databases as opposed to hospital discharge lists. In other words, some patients may be funneled through the hospital system differently with the same amount of pain intensity by virtue of being, for instance, older. This is not detrimental to the patient’s care, as it may indeed be appropriate based on the significant risk factors found for poor pain recovery. In fact, using knowledge of the predictors that increase risk to determine disposition of patients is exactly what studies of this nature hope to persuade into practice. But, different medical processing of high initial pain intensity patients determined to be more at risk than another patient with pain at the same level could confound the relationship between initial pain intensity and follow-up pain.

Furthermore, high initial pain intensity as a prognostic factor is difficult to tease away from treatments, like prescribing opioids. It is probable that patients reporting greater pain in the ED are more likely to receive pain medications, and this may affect the outcomes at follow-up. To complicate this notion further, different types of patients, for example less educated and older aged, are less likely to be treated with opioids. (85) The differential discharge and treatment statuses that may arise from high initial pain intensity reports by patient type could conceivably skew study results.

Interestingly, the Walton et al analysis showed that older age was not a significant predictor of persistent pain, but several of the studies included did report such significance. (68) The review and meta-analysis included mainly cohorts that limited enrollment to younger patients (i.e. those that did not include older adults), which the authors acknowledge by stating that the articles reviewed had no standardized age range or even definitions of older patients, making conclusions about the importance of age as a predictor difficult to ascertain. (68) The
strength of the current review lies in the inclusion of only cohorts that included older patients, defined as MVC-victims over 65 years of age. In order to make the claim that advanced age is in fact predictive of the development of persistent pain after MVC-related injury, it is necessary that the older drivers be accounted for in the group of participants. With many studies arbitrarily limiting participation to patients under 55 or 65, an important population of drivers is missed. This review allows the conclusion that age is an apparently strong predictor of pain after long-term follow-up for accident sufferers across the lifespan.

Another similar systematic review by Scholten-Peeters et al focuses on prognostic factors identified for whiplash victims for persistent disability in 29 prospective cohorts, and the findings suggested that only high initial pain intensity was predictive of functional outcome. (67) The authors found no strong association between poor outcomes and age, gender, or psychological distress. The pain intensity findings were only predictive of functional outcome, and the authors were unable to glean the data to concurrently assess pain outcomes. Furthermore, only three out of 29 independent cohorts examined specifically included patients over 65 and none were inclusive of patients over 70. Again, with many MVC patients being older adults, these conclusions are difficult to generalize to the population over 65 years of age.

It is important to note that while the studies included in this review were inclusive of MVC victims over 65 years of age, only one included any patient over 70. It is possible that some excluded studies were inclusive of older adults and simply commented age over 18, without explicitly stating that some patients were over 65. (86-88) Defining older age as over 65 is common in research, but remains an arbitrary cut point. Many people continue to drive after 70 years of age, and this population is estimated to increase in size exponentially in the coming years. As this surge in older drivers occurs, it will be increasingly imperative to better
characterize the outcomes of MVC for this group by enlarging the number of older adults in the cohorts.

Only four studies out of 47 fulfilled the criteria for measuring pain outcomes in a group of MVC-victims with some patients over 65 years of age. Of those four, only one (Kasch et al) could be considered to be of good quality, primarily because the others displayed a high risk of selection bias through mail recruitment with relatively low response rates, a failure to characterize the differences and similarities between participants and refusers, and high drop out rates over the follow-up periods. (82) This highlights the difficulty faced by researchers to attain information from patients seen in emergency departments and discharged home. Generally by virtue of limited resources, studies often resort to mail questionnaires for both recruitment and follow-up, which imparts a necessary degree of potential selection bias. Selection bias could be somewhat curtailed with improved recruitment strategies like face-to-face emergency department enrollment with baseline attained in the hospital and phone call or in-person follow-up versus mail only questioning.

The possibility that publication bias affects the results of this and other systematic reviews cannot be excluded. Studies that conclude significant results are more likely to lead to multiple publications. (89) One way that the current article combats this effect is through limiting the articles to one report of each cohort, thus avoiding inflation of significant findings by repeated measures of the same factors. Nonetheless, publication bias is an important consideration in assessing the findings of a systematic review of published literature.

Several other limitations of the current review are noteworthy. The quality assessment tool developed for this systematic review was based on previously published forms by Hudak et al, Scholten-Peeters et al, and on the suggestions of the PRISMA statement for the reporting of
systematic reviews. (67, 80, 90) Decisions about the quality of reporting was based on popularly accepted cut-offs for acceptable attrition rates, but is not reflective of any experimentally supported rate. Furthermore, concepts like risk of bias were qualitative assessments based on the cumulative assessment of the article, and are subject to measurement bias. Importantly, the current review was limited to one reviewer, with all inclusion/exclusion, quality, and data extraction decisions made by this individual. Both the quality assessment tool and the data extraction form were produced as a standardized way to assess each article and to help alleviate some of this measurement bias.

The generalizability of the results of the studies reviewed herein is also a potential issue. All four studies were conducted in countries with a universal health care system. This may lead to substantial differences between MVC-victims in United States and the study populations in such factors as the number and kind presenting to the ED, the initial complaints, the propensity to seek care after the MVC as an outpatient, and so forth. It is difficult to know what effect social insurance has on health outcomes without comparing the findings to a suitable American cohort, which is currently unavailable. Therefore, caution should be taken in generalizing the predictive factors for persistent pain after MVC found in this review to the patient population of the United States.

5. Conclusions

Patients involved in motor vehicle collisions are at a substantial risk for developing persistent pain symptoms after the crash. (71, 81, 82) Predictors of persistent pain at follow-up are likely myriad and are difficult to assess in individual studies, and further complicated by study designs that are subject to selection bias. Although inconsistent, evidence suggests that demographic features like age and gender, crash characteristics, psychological factors, and
health/pain experiences usher patients into recovery or non-recovery from MVC-related painful injury. (10, 14, 91) Unfortunately, with so much heterogeneity in samples, factors studied, measurements, and outcomes, very little consensus can be reached regarding the true predictive factors for the development of persistent pain post-MVC. The current systematic review revealed that high initial pain intensity and age were consistently linked to pain at follow-up. The results of this review also illustrate that limited research includes the older adult population over 65 years of age, and with the group included in analyses, age is a strong prognostic indicator for pain outcomes.
Figure 1. Flow of decision-making for systematic review inclusion

89 records identified through database search and reference lists

47 relevant based on subject/title

43 excluded
Reasons excluded:
No pain measure/disability only (2)
No patients over 65 or unknown age range (20)
Follow-up less than 6 weeks or > 1 year (4)
Injuries not by MVCs (5)
Systematic review (4)
Widespread pain/Fibromyalgia (3)
Duplicate cohort (3)
No pain measure at baseline (2)

4 included in review
<table>
<thead>
<tr>
<th>Authors(year)</th>
<th>Sampling site, recruitment</th>
<th>Sample size</th>
<th>Follow-up period</th>
<th>Pain Outcome</th>
<th>% Follow-up Pain</th>
<th>Number of factors studied</th>
<th>Significant predictors</th>
<th>Age range</th>
<th>Risk of bias</th>
<th>Study quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atherton et al (2006)</td>
<td>United Kingdom, emergency departments-mail</td>
<td>765</td>
<td>1m, 3m, 12m</td>
<td>Pain in neck for one day or more in prior week</td>
<td>27</td>
<td>28</td>
<td>Age, Psychological distress post-injury, pre-MVC pain, injury severity score, neck pain post-injury, being in a non-car at MVC</td>
<td>17-70</td>
<td>Moderate-mail recruitment only, &gt;35% attrition rate</td>
<td>Fair-selection bias, mail only</td>
</tr>
<tr>
<td>Kasch et al (2008)</td>
<td>Denmark, emergency departments and primary care-physician referral</td>
<td>688</td>
<td>3m, 6m, 12m</td>
<td>VAS neck pain</td>
<td>~40(^1)</td>
<td>10</td>
<td>Age, Gender, neck pain post-injury</td>
<td>18-70</td>
<td>Low-no sig differences between participants and refusers, low attrition rate, mail recruitment</td>
<td>Good</td>
</tr>
<tr>
<td>Brison et al (2000)</td>
<td>Canada, ED computer database-mail</td>
<td>446</td>
<td>1,2,3,6,9,12,18,24m</td>
<td>Frequency and VAS severity of pain</td>
<td>36</td>
<td>25</td>
<td>Age, Gender, height, BMI, past WAD</td>
<td>18-70</td>
<td>Moderate-refusers not characterized, mail only recruitment</td>
<td>Fair-selection bias, no confounders assessed</td>
</tr>
<tr>
<td>Gun et al (2005)</td>
<td>Australia, emergency department-physician recruited</td>
<td>147</td>
<td>12m</td>
<td>VAS and pain outcome score</td>
<td>Not reported</td>
<td>10</td>
<td>Age, Litigation, pain post-injury, psychological distress after MVC</td>
<td>14.1-77.9</td>
<td>Moderate-many excluded</td>
<td>Fair-small sample, selection bias</td>
</tr>
</tbody>
</table>

\(^1\) Based on a Figure 2 of article
**Evidence Table 2.** Strength of evidence per predictor variable

<table>
<thead>
<tr>
<th>Predictor</th>
<th># Significant findings</th>
<th>Strength of evidence&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>4</td>
<td>Strong</td>
</tr>
<tr>
<td>Initial pain intensity</td>
<td>3</td>
<td>Strong</td>
</tr>
<tr>
<td>Gender</td>
<td>2</td>
<td>Moderate</td>
</tr>
<tr>
<td>Psychological distress</td>
<td>2</td>
<td>Moderate</td>
</tr>
<tr>
<td>Injury severity</td>
<td>1</td>
<td>Unclear</td>
</tr>
<tr>
<td>Height</td>
<td>1</td>
<td>Unclear</td>
</tr>
<tr>
<td>Litigation</td>
<td>1</td>
<td>Unclear</td>
</tr>
<tr>
<td>Vehicle non-car</td>
<td>1</td>
<td>Unclear</td>
</tr>
<tr>
<td>Past WAD</td>
<td>1</td>
<td>Unclear</td>
</tr>
<tr>
<td>BMI</td>
<td>1</td>
<td>Unclear</td>
</tr>
</tbody>
</table>

<sup>1</sup> High, moderate, unclear
**Appendix A. Risk of bias/quality assessment form**

<table>
<thead>
<tr>
<th>Sampling/Study population</th>
<th>+/-/?*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational definition of cases with exclusion and inclusion criteria clear</td>
<td></td>
</tr>
<tr>
<td>Source population was adequately described</td>
<td></td>
</tr>
<tr>
<td>Refusers were characterized and differences noted (if any) between participants and refusers</td>
<td></td>
</tr>
<tr>
<td>An adequate number of patients were in the older adult (over 65) age group for comparisons</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Methodology</th>
<th>+/-/?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain was measured using a valid scale (i.e. VAS)</td>
<td></td>
</tr>
<tr>
<td>Evidence given that patients lost to follow-up were similar at baseline to participants who completed study</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Statistical Analysis</th>
<th>+/-/?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appropriate univariate analyses were presented</td>
<td></td>
</tr>
<tr>
<td>Appropriate multivariate analyses were utilized</td>
<td></td>
</tr>
<tr>
<td>The sample size was adequate for number of variables investigated</td>
<td></td>
</tr>
<tr>
<td>Appropriate confounders were controlled for in final analysis</td>
<td></td>
</tr>
<tr>
<td>Low risk of selection bias</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prognostic factors</th>
<th>+/-/?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prognostic factors were measured using valid and reliable instruments</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Results</th>
<th>+/-/?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main pain outcome(s) were presented clearly</td>
<td></td>
</tr>
<tr>
<td>Results of prognostic factors were presented clearly</td>
<td></td>
</tr>
<tr>
<td>Follow-up occurred for &gt;=80% at follow-up</td>
<td></td>
</tr>
<tr>
<td>Follow-up occurred at the same point post-injury for all participants</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Risk of bias**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality rating***</td>
</tr>
</tbody>
</table>

*+=sufficient evidence that study fulfills criteria -= does not fulfill ?=unclear
**Risk of bias as judged by reviewer to be high, moderate, or low
***Quality rating options are good, fair, or poor
**Appendix B.** Data extraction form

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study name</td>
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<td>Author</td>
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<td>Study design</td>
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<td>Recruitment method</td>
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<td>Sample size</td>
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<td>Source population</td>
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<td>Inclusion/exclusion criteria</td>
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<td>Predictors measured, (sig +/-)</td>
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<td>Follow-up period</td>
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<td>Number of drop outs</td>
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<td>Pain measure, result</td>
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References

85. Platts-Mills TF and Hunold KM and Bortsov AV and others. More educated emergency department patients are less likely to receive opioids for acute pain. ; 2012.