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Effect of pain location and duration on life function in the year after motor vehicle collision

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ABSTRACT

Persistent musculoskeletal pain is common after motor vehicle collision (MVC) and often results in substantial disability. The objective of this study was to identify distributions of post-MVC pain that most interfere with specific life functions and that have the greatest interference with aggregate life function. Study data were obtained from a prospective longitudinal multicenter emergency department–based cohort of 948 European Americans experiencing MVC. Overall pain (0–10 numeric rating scale [NRS]), pain in each of 20 body regions (0–10 NRS), and pain interference (Brief Pain Inventory, 0–10 NRS) were assessed 6 weeks, 6 months, and 1 year after MVC. After adjustment for overall pain intensity, an axial distribution of pain caused the greatest interference with most specific life functions (R^2 = 0.15–0.28, association P values of <.001) and with overall function. Axial pain explained more than twice as much variance in pain interference as other pain distributions. However, not all patients with axial pain had neck pain. Moderate or severe low back pain was as common as neck pain at week 6 (prevalence 37% for each) and overlapped with neck pain in only 23% of patients. Further, pain across all body regions accounted for nearly twice as much of the variance in pain interference as neck pain alone (60% vs 34%). These findings suggest that studies of post-MVC pain should not focus on neck pain alone.
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1. Introduction

Motor vehicle collisions (MVCs) result in 50 million injuries worldwide and almost 4 million U.S. emergency department (ED) visits each year [36,49]. In the United States, approximately 90% of individuals presenting to the ED for care after MVC are discharged to home after ED evaluation [41]. Health care expenses and productivity loss from persistent post-MVC pain cost an estimated $29 billion per year in the United States alone [16,20]. The development of effective interventions to prevent persistent pain after MVC and the advancement of understanding to guide these interventions remain important international research priorities [29,58].

Most contemporary studies of post-MVC pain focus primarily or exclusively on pain in the neck region [32,45]. Although pain location has been linked to function and psychological conditions in patients with chronic nonmalignant pain [14,18,23] and the extent of pain has been consistently linked to pain interference in different patient populations [1,6,35], little is currently known

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regarding patterns of pain experienced by individuals after MVC. In addition, little is currently known regarding how these patterns of pain influence overall pain interference and specific functional disability and this influence evolves over time. A better understanding of the association between post-MVC pain distribution and functional outcomes has the potential to enrich our understanding of which individuals are at greatest risk for disability and of the functional challenges experienced by patients with specific locations/distributions of pain. Understanding how post-MVC pain location and distribution impact specific life functions would also be valuable to practitioners designing treatment interventions for individuals with persistent post-MVC pain and assessing the functional outcomes of these interventions. In addition, evaluating the influence of pain duration and of individual demographic characteristics on activity interference can provide us with additional information regarding how the functional toll of pain of a given severity and distribution changes over time.

We previously evaluated the prevalence of pain in individual body regions in the hours after MVC [8] and 6 weeks after MVC [33]. In these studies, we found that pain in specific body areas in the axial region (eg, neck, shoulders, back) were most commonly reported. However, patients do not experience individual body regions of pain in isolation but rather experience patterns of pain distributed across body regions. In this study, we sought to assess patterns of persistent pain across body regions that are common after MVC. Also, most importantly, we sought to assess the impact of different patterns of persistent pain on pain interference with specific life functions and with overall function. Because pain in axial regions has been associated with worse physical and mental health in the general population [11,31,52] and because movement of the neck and back are necessary to perform most life functions, we hypothesized that an axial distribution of pain after MVC would result in greater disability than other pain distributions. In addition, we also evaluated the influence of post-MVC pain duration and of individual sociodemographic factors (age, sex, and education) on pain-related functional interference.

2. Methods

2.1. Study design and participants

This multicenter ED-based observational cohort study evaluated pain and functional outcomes 6 weeks, 6 months, and 1 year after MVC. Participating centers included 8 EDs in 4 no-fault insurance states in the United States (Massachusetts, Florida, Michigan, and New York). Recruitment took place between February 2009 and October 2011. Institutional review board approval for the study was obtained at each study site, and each participant provided written informed consent. Complete information regarding study design, procedures, and methods has previously been described [39].

Eligible patients were alert, oriented, English-speaking European Americans 18 to 65 years of age who were present to one of the study site EDs for evaluation after MVC. Patients were included regardless of the location of impact to the vehicle; location of impact has been shown to not be a strong determinant of post-MVC pain distribution [4,28]. Patients with spinal fracture or dislocation; neurologic signs, including decreased/absent deep tendon reflexes or weakness; skull fracture, facial fracture, intracranial injury, or long bone fracture; and laceration with significant hemorrhage, as well as those presenting more than 24 h after injury, were excluded, as were prisoners, pregnant women, and individuals who could read English. Clinically unstable patients or patients who had potentially life-threatening injuries were also excluded.

2.2. Data collection procedures

Patients were screened and recruited by research assistants at each ED site. Baseline interviews were completed in the ED; follow-up interviews were completed via Internet self-report survey or via telephone interview 6 weeks, 6 months, and 1 year after MVC. Each research assistant conducting follow-up interviews completed a study training module followed by an interview with a standardized mock patient. Comparison of mock patient data across research assistants demonstrated an error rate of 1.3%.

2.3. Measures

Demographic information (age, sex, education, relationship/marital status) was assessed during the baseline ED interview using standardized questionnaire items. Injury scoring of each patient injury was performed using the Abbreviated Injury Scale (AIS), an anatomically based scoring system that classifies each injury according to its relative severity on a 6-point ordinal scale [3]. Pain intensity, distribution, and pain interference were assessed via telephone interview or a Web-based questionnaire. Location and intensity of pain symptoms during the past week were assessed 6 weeks, 6 months, and 1 year after MVC using the modified Regional Pain Scale [56]. Pain intensity in each region was evaluated via numeric rating scale (NRS) from 0 (no pain) to 10 (maximum possible pain). Overall pain intensity was also assessed using the 0 to 10 NRS. Widespread pain was defined according to American College of Rheumatology 1990 criteria [57].

Pain interference with life functions was assessed using the Brief Pain Inventory (BPI) [10,26]. The relationship between pain intensity and pain interference with life function (disability) using BPI subscales has been demonstrated across multiple studies [10,26,48]. BPI subscales assess interference with 7 life functions (general activity, walking ability, mood, relations with other people, sleep, and enjoyment of life) on a 0 to 10 scale, where 0 represents "does not interfere" and 10 indicates "interferes completely" [10]. Pain interference scores assessed at 6 weeks were used in statistical analyses, except for analyses evaluating the effect of time from trauma, in which pain interference scores from the respective time point were used.

2.4. Statistical analyses

Values of interference subscales were averaged to calculate a pain interference total score for each individual [10]. Reliability of this score was assessed by Cronbach's α and by evaluating correlation coefficients between this score and individual subscale scores.

Principal component analysis (PCA) was used to reduce the dimensionality of the regional pain data (obtained from the 20-item regional pain scale) and identify specific post-MVC pain distributions. The PCA method was used to extract the components. The number of components to retain was determined by applying Kaiser-Guttman criterion [59] and by visual exploration of a scree plot. A varimax (orthogonal) and oblique rotation were applied, and the results were compared for interpretability. In interpreting the rotated factor pattern, an item was determined to load on a given component if the factor loading was 0.50 of greater for that component [19]. Items were allowed to load on more than 1 component only if the anatomical location of the item suggested its contribution to more than 1 pain region. Association of the principal components with pain interference subscales and total score was performed using a general linear model. Adjustment for participant age and sex was performed by running regression models with these predictors and outputting the residuals. The strength of

association between each principal component and these residuals was evaluated using the coefficient of determination (R^2).

Association of sociodemographic factors with pain interference outcomes was performed using a general linear model adjusted for overall pain intensity and pain distribution (identified using the PCA described above). Association of pain extent (widespread pain vs regional pain) was adjusted for pain intensity only.

The effect of pain duration on pain interference was assessed using a linear mixed model with pain interference total score 6 weeks, 6 months, and 1 year after MVC as outcomes. Within-subject correlation of model residuals was accounted for by using an unstructured covariance matrix. All statistical analyses were performed by SAS software, version 9.2 (SAS Institute, Cary, NC). P values of <.05 were considered statistically significant.

Mean pain interference total scores and bootstrap-derived 95% confidence intervals for each overall pain value were plotted, stratified by the predictor of interest (ie, age tertile, sex, educational attainment, relationship status, widespread pain, and time of assessment). Computation of plotted statistics and figure plotting were performed using the R package ggplot2 [54].

3. Results

A total of 10,629 patients admitted to the ED after MVC were screened; 1,416 met the eligibility criteria, 969 consented to participate in the study, and 948 participants completed baseline evaluations (Fig. 1). Outcome evaluations were completed in 859 of 948 (91%) of participants at 6 weeks, 839 of 948 (89%) of participants at 6 months, and 861 of 948 (91%) of participants at 1 year. Sociodemographic characteristics of participants evaluated at each time point are presented in Table 1. Consistent with study exclusion criteria, participants had only minor injury: 99% of participants had a maximum AIS score of 1. The remaining 1% had an AIS score of 2. Pain in the head, neck, shoulder, and back regions was most common (Fig. 2); 437 of 859 (51%) participants had moderate or severe axial pain at 6 weeks. Individuals with pain in these regions were also most likely to report widespread pain (Fig. 2). Overall, widespread pain was present in 179 of 859 (21%) individuals at 6 weeks. Across follow-up time points, pain interference summary scores showed high reliability (Cronbach's $\alpha = 0.94$–0.96) and were moderately correlated with overall pain scores (Table 2). Pain interference subscales were positively correlated with each other (Pearson correlation coefficients 0.55–0.86) (Table 2).

3.1. Principal components of pain distribution at week 6 after MVC and their association with pain interference

PCA was performed to reduce the dimensionality of pain location data. PCA of the responses to the 20-item Regional Pain Scale questionnaire at the 6-week time point identified 5 components with eigenvalues greater than 1 (termed PC1–PC5). Visual examination of a scree plot was also consistent with 5 meaningful factors. Together, these 5 factors accounted for 66% of the total variance in the Regional Pain Scale.

Initially both varimax (orthogonal) and oblique rotation were performed. After oblique rotation, the correlations between the components were in the range 0.17 to 0.37. Both rotations yielded nearly identical interpretable distribution of scale items across the 5 factors (Table 3). Because orthogonal principal components allow us to assess the independent contribution (ie, R^2) of each component in pain interference models, orthogonal rotation is preferred even if the data suggest correlation between components [47]. Therefore, only orthogonal rotation results were retained for subsequent analyses. Pain in the hips and upper and lower legs had the highest loadings (>0.50) on PC1 (termed "Leg pain"). Head, neck, shoulders, and upper and lower back pain had the highest loadings on PC2 ("Axial pain"). Pain in the right and left sides of the jaw contributed most to PC3 ("Jaw pain"). Pain in the right shoulder, right upper arm, and right lower arm loaded on PC4 ("Right arm pain"). Finally, pain in the left upper arm, left lower arm, and chest loaded on PC5 ("Left arm pain"). Of note, shoulder pain loaded both on the corresponding arm and the axial region. Abdominal pain did not load on any of the factors.

Each principal component was significantly associated with each interference subscale and total interference score (all $P < .001$). Axial pain (PC2) explained more variance in individual interference subscales ($R^2 = 0.15$–0.28) than pain in other regions (Fig. 3), with generally more than twice as much influence on specific aspects of disability as pain in other regions (Fig. 3). The single exception was interference in walking ability, which was best explained by leg pain ($R^2 = 0.23$). Left and right arm pain (PC3 and PC4) explained 2% to 5% of the variance in each interference subscale, and jaw pain explained less than 2% of total variance (Fig. 3). Similar results were obtained for pain and pain interference 6 months and 1 year after MVC (data not shown).

Because axial pain was more prevalent than pain in other regions and more commonly associated with widespread pain (Fig. 2), we repeated the analyses after adjustment for number of pain regions. Axial pain continued to have the greatest influence on pain interference after adjustment. Axial pain explained at least 6 times more variance in the interference subscales than any other body region, with the exception of walking ability, where leg pain remained most influential (data not shown).

3.2. Sociodemographic predictors of pain interference

General linear models were used to assess sociodemographic predictors of pain interference, adjusting for overall pain intensity and pain distribution. Sex and age were highly significant predictors of pain interference (Table 4, Fig. 4A, B). Despite women reporting more severe overall pain than men, interference with life function from a given distribution/severity of pain was greater in men than in women. This difference was present for overall interference and for all interference subscales except mood and walking ability (Table 4). Among the age tertiles, the youngest group (18–26 years) reported lower pain interference in all subscales than the older age groups (27–41 and 42–65 years; Table 4 and Fig. 4A). After additional adjustment for age and sex, more educated participants reported higher pain interference with sleep, but not with other interference subscales or total interference. Relationship status was not associated with pain interference (Table 4).

3.3. Widespread pain and pain interference

Pain extent was a significant predictor of pain interference, independent of the severity of pain. Participants with widespread pain had substantially higher pain interference with each of the evaluated life functions (Table 4, Fig. 4C).

3.4. Time from trauma and pain interference

After controlling for overall pain severity and pain distribution, time from trauma was inversely associated with pain interference (Table 4, Fig. 4D). Study participants reported less interference with life functions at month 6 and year 1 evaluations compared to the week 6 evaluation, with a 38% reduction in pain interference observed between 6 weeks (mean interference 2.3 ± 0.1 units) and 1 year (mean interference 1.4 ± 0.1 units).

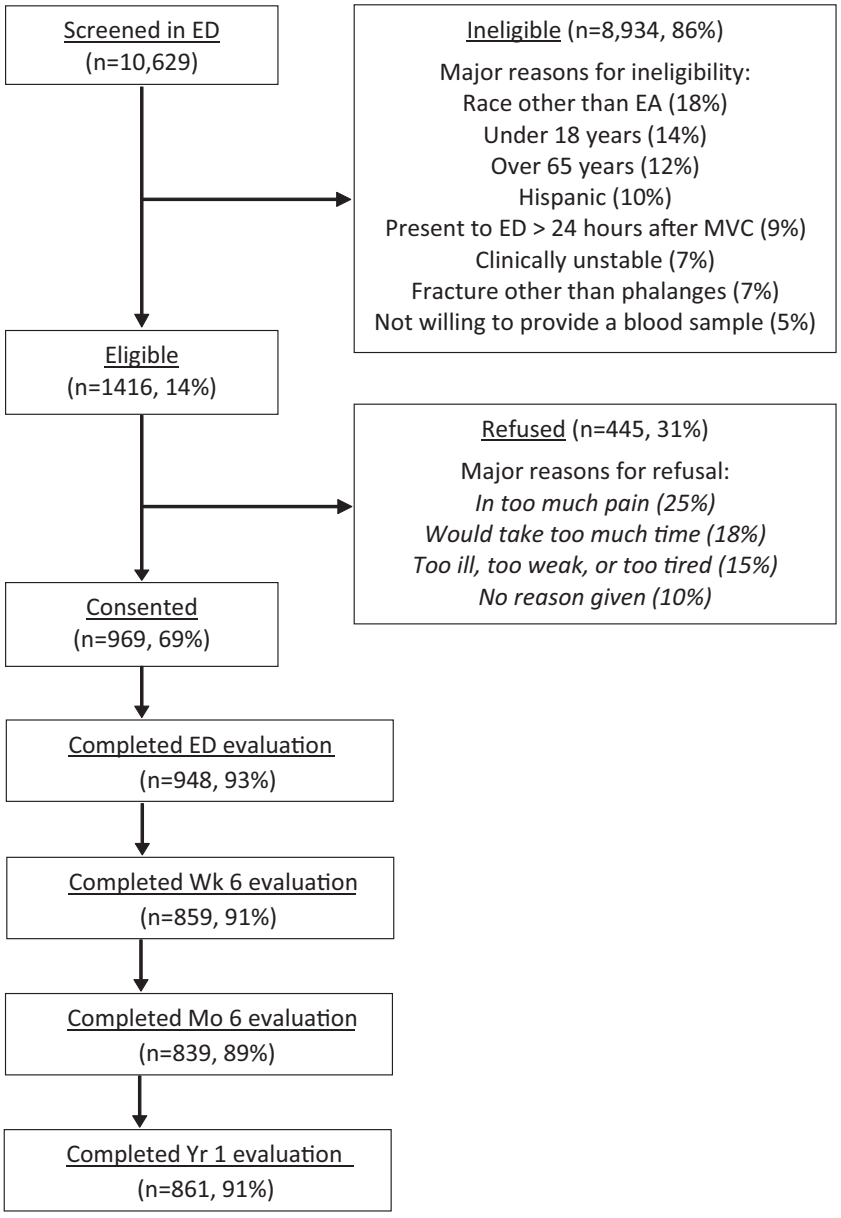


Fig. 1. Study flow chart.

4. Discussion

In this study, we sought to determine which locations/distributions of pain after MVC most interfere with specific life functions and have the greatest influence on overall disability. After adjustment for overall pain intensity, axial pain (pain in the neck, shoulders, and upper and lower back) was found to have the greatest impact on 6 of the 7 specific life functions assessed; this site also had the greatest influence on overall interference. In each of these areas, axial pain had more than twice as much impact on function as pain in other body regions. Widespread pain also had much more impact than regional pain. Pain of a specific intensity and distribution had a greater impact on disability among men and among those not in the youngest tertile of age. Across all participants, the degree of functional interference resulting from a specific intensity and distribution of pain decreased over time.

As hypothesized, we found that axial pain showed the strongest association with pain interference. Approximately half of study participants had moderate or severe axial pain at 6 weeks. However, not all patients with axial pain had neck pain. Moderate or severe low back pain was as common as neck pain at week 6 (prevalence 37% for each) and overlapped with neck pain in only 23% of patients. Further, pain across all body regions accounted for nearly twice as much of the variance in pain interference as neck pain alone (60% vs 34%). These results indicate that pain in body regions other than the neck contributes substantially to pain-related disability after MVC and suggest that studies of post-MVC pain outcomes should include a comprehensive assessment of pain across body regions.

These findings have several important implications for the treatment of individuals experiencing musculoskeletal pain after MVC. First, interventions seeking to achieve the greatest functional improvement should focus on axial pain outcomes, as these regions appear to have the greatest influence on disability. In addition, practitioners treating individuals with post-MVC axial pain disorders and performing serial outcome assessments to monitor

Table 1
Sociodemographic characteristics of study participants at baseline, week 6, month 6, and year 1 after motor vehicle collision.

Characteristic	ED (*N* = 948)		Week 6 (*N* = 859[a])		Month 6 (*N* = 839[a])		Year 1 (*N* = 861[a])	
	n	%	*n*	%	*n*	%	*n*	%
Sex								
Male	373	39	321	37	318	38	321	37
Female	575	61	538	63	521	62	540	63
Age tertile								
18–26 y	315	33	272	32	263	31	272	32
27–41 y	319	34	289	34	283	34	292	34
42–65 y	314	33	298	35	293	35	297	34
Education								
High school or less	351	37	335	39	328	39	334	39
Some college	369	39	330	38	325	39	332	39
College degree or more	226	24	193	22	185	22	194	23
Missing	2	...	1	...	1	...	1	...
Relationship								
None	297	32	265	31	254	31	259	30
Not living together	146	16	127	15	115	14	130	15
Living together	492	53	457	54	460	55	462	54
Missing	13	...	10	...	10	...	10	...

ED, emergency department.
[a] Number of participants with no missing data for Brief Pain Inventory.

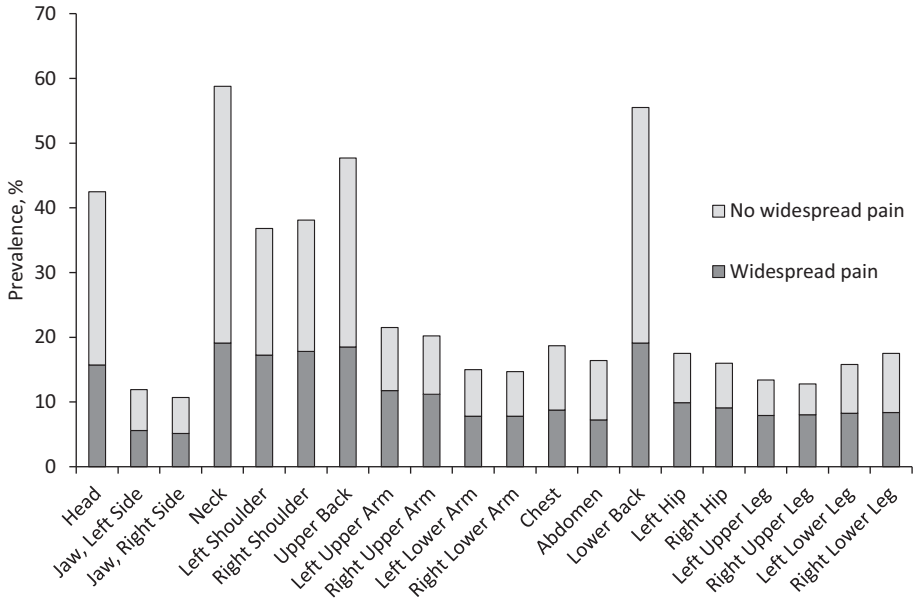


Fig. 2. Prevalence of pain by body region 6 weeks after motor vehicle collision, and proportion of patients who had pain in each body region who had widespread pain. Widespread pain was defined according to American College of Rheumatology 1990 criteria [57].

Table 2
Mean Brief Pain Inventory pain interference subscale scores and overall pain at week 6, month 6, and year 1 after motor vehicle collision.

Scale	Intercorrelations (Pearson r) between interference subscales at week 6						Week 6	Month 6	Year 1
	1	2	3	4	5	6	Mean ± SD	Mean ± SD	Mean ± SD
Pain interference total							2.4 ± 2.6	1.6(2.4)	1.4(2.2)
1. General activity							2.8 ± 3.1	1.8(2.7)	1.6(2.6)
2. Enjoyment of life	0.76						2.3 ± 3.1	1.5(2.6)	1.3(2.5)
3. Mood	0.76	0.78					2.9 ± 3.2	1.7(2.7)	1.5(2.5)
4. Normal work	0.86	0.75	0.73				2.8 ± 3.3	1.8(2.9)	1.6(2.7)
5. Relations with other people	0.62	0.74	0.73	0.64			1.6 ± 2.7	1.1(2.4)	0.9(2.1)
6. Sleep	0.71	0.68	0.68	0.68	0.60		2.9 ± 3.3	2.0(3.0)	1.6(2.8)
7. Walking ability	0.67	0.64	0.60	0.68	0.57	0.55	1.5 ± 2.6	1.1(2.3)	1.1(2.3)
Cronbach's α (standardized)							0.94	0.95	0.96
Overall pain intensity							3.8 ± 2.8	3.1(2.8)	3.2(2.9)
Pearson r[a]							0.72	0.70	0.66

[a] Pearson correlation between pain interference summary score and overall pain severity (0–10 on numerical rating scale).

Table 3
Loadings of individual regional pain scores on derived principal components at week 6 after motor vehicle collision.

Region	PC1, "Leg pain"	PC2, "Axial pain"	PC3, "Left arm pain"	PC4, "Right arm pain"	PC5, "Jaw pain"
Head	0.09	0.64[a]	0.17	0.16	32
Jaw, left side	0.19	0.19	0.19	0.06	0.88[a]
Jaw, right side	0.25	0.15	0.12	0.14	0.88[a]
Neck	0.11	0.82[a]	0.12	0.23	0.16
Left shoulder	0.02	0.64[a]	0.51[a]	0.08	0.05
Right shoulder	0.10	0.56[a]	0.08	0.64[a]	0.06
Upper back	0.21	0.76[a]	0.15	0.16	0.08
Left upper arm	0.12	0.39	0.73[a]	0.21	0.14
Right upper arm	0.20	0.26	0.23	0.79[a]	0.14
Left lower arm	0.20	0.12	0.75[a]	0.28	0.10
Right lower arm	0.26	0.07	0.34	0.75[a]	0.08
Chest	0.30	0.09	0.48	0.20	0.19
Abdomen	0.41	0.14	0.25	0.03	0.21
Lower back	0.41	0.67[a]	0.06	−0.05	0.00
Left hip	0.60[a]	0.26	0.39	−0.10	0.14
Right hip	0.70[a]	0.29	−0.03	0.21	0.15
Left upper leg	0.68[a]	0.17	0.40	−0.03	0.12
Right upper leg	0.78[a]	0.14	−0.01	0.31	0.07
Left lower leg	0.62[a]	0.04	0.34	0.06	0.14
Right lower leg	0.66[a]	0.03	0.04	0.30	0.09

PC, principal component.
[a] Factor loadings >.50.

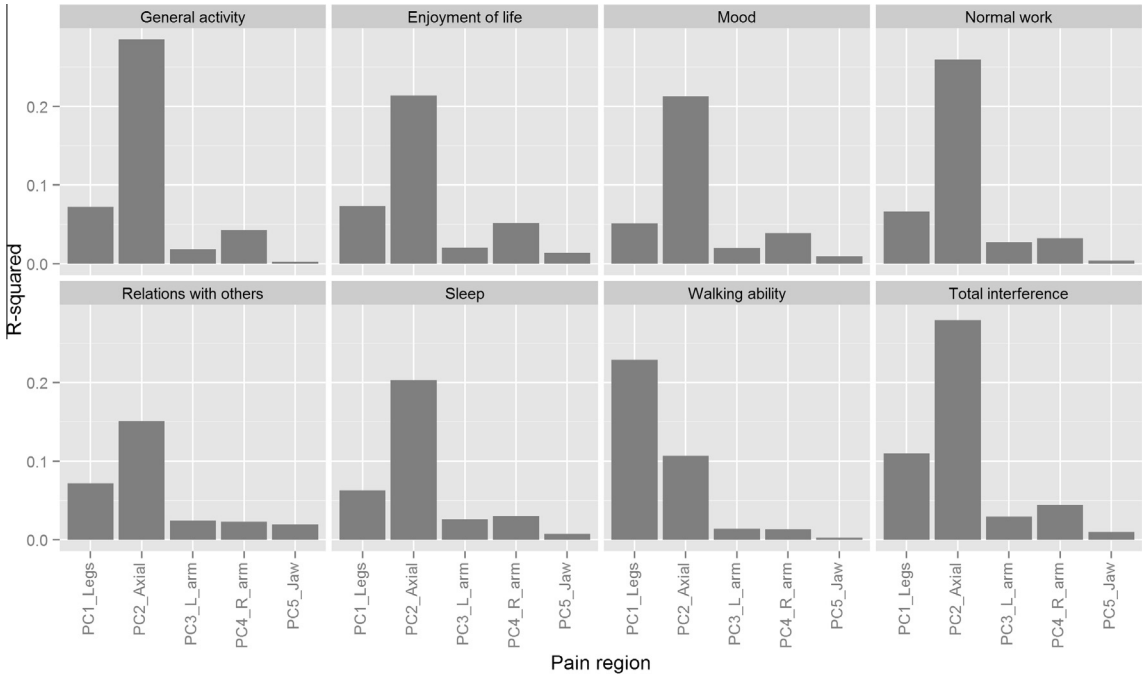


Fig. 3. Proportion of total variance (R^2) in interference scales explained by regional pain factors, adjusted for participant age and sex.

Table 4
Association of sociodemographic and pain symptom characteristics with pain interference subscale scores after motor vehicle collision.[a]

Characteristic	Interference subscale															
	General activity		Enjoyment of life		Mood		Normal work		Relations with other people		Walking ability		Sleep		Total Interference	
Sex[b]																
Male	3.2	(0.1)	2.7	(0.1)	3.0	(0.1)	3.2	(0.1)	1.8	(0.1)	1.6	(0.1)	3.2	(0.1)	2.7	(0.1)
Female	2.6	(0.1)	2.1	(0.1)	2.8	(0.1)	2.5	(0.1)	1.4	(0.1)	1.4	(0.1)	2.7	(0.1)	2.2	(0.1)
P	<.001		<.001		.37		<.001		.005		.063		.021		<.001	
Age[b]																
18–26 y	2.5	(0.1)	1.9	(0.1)	2.5	(0.1)	2.3	(0.1)	1.2	(0.1)	1.2	(0.1)	2.9	(0.2)	2.1	(0.1)
27–41 y	3.0	(0.1)	2.7	(0.1)	3.1	(0.1)	3.1	(0.1)	1.6	(0.1)	1.5	(0.1)	3.0	(0.1)	2.6	(0.1)
42–65 y	3.0	(0.1)	2.4	(0.1)	2.9	(0.1)	3.0	(0.1)	1.8	(0.1)	1.7	(0.1)	2.8	(0.1)	2.5	(0.1)
P	.003		<.001		.019		<.001		.008		.005		.82		<.001	
Education[b]																
High school or less	2.9	(0.1)	2.3	(0.1)	2.7	(0.1)	2.9	(0.1)	1.5	(0.1)	1.5	(0.1)	2.6	(0.1)	2.4	(0.1)
Post–high school	2.8	(0.1)	2.4	(0.1)	2.9	(0.1)	2.8	(0.1)	1.5	(0.1)	1.4	(0.1)	3.0	(0.1)	2.4	(0.1)
College or more	2.6	(0.1)	2.1	(0.2)	2.9	(0.2)	2.5	(0.2)	1.5	(0.2)	1.5	(0.1)	3.2	(0.2)	2.3	(0.1)
P	.32		.47		.60		.24		.98		.90		.018		.81	
Relationship status[b]																
No relationship	2.8	(0.1)	2.4	(0.1)	2.8	(0.1)	2.8	(0.1)	1.4	(0.1)	1.6	(0.1)	3.1	(0.2)	2.4	(0.1)
Not living together	2.7	(0.2)	1.9	(0.2)	2.9	(0.2)	2.6	(0.2)	1.8	(0.2)	1.4	(0.2)	2.7	(0.2)	2.3	(0.1)
Living together/married	2.9	(0.1)	2.4	(0.1)	2.9	(0.1)	2.8	(0.1)	1.5	(0.1)	1.4	(0.1)	2.8	(0.1)	2.4	(0.1)
P	.58		.10		.87		.73		.31		.21		.30		.79	
Pain distribution[b]																
Widespread	3.9	(0.2)	3.5	(0.2)	3.8	(0.2)	4.0	(0.2)	2.6	(0.2)	2.4	(0.2)	3.6	(0.2)	3.4	(0.1)
Regional	2.5	(0.1)	2.0	(0.1)	2.6	(0.1)	2.5	(0.1)	1.3	(0.1)	1.2	(0.1)	2.7	(0.1)	2.1	(0.1)
P	<.001		<.001		<.001		<.001		<.001		<.001		<.001		<.001	
Follow-up time point[c]																
Week 6	2.7	(0.1)	2.2	(0.1)	2.7	(0.1)	2.6	(0.1)	1.5	(0.1)	1.4	(0.1)	2.7	(0.1)	2.3	(0.1)
Month 6	1.9	(0.1)	1.5	(0.1)	1.8	(0.1)	1.9	(0.1)	1.1	(0.1)	1.1	(0.1)	2.0	(0.1)	1.6	(0.1)
Year 1	1.6	(0.1)	1.3	(0.1)	1.6	(0.1)	1.6	(0.1)	0.9	(0.1)	1.0	(0.1)	1.7	(0.1)	1.4	(0.1)
P	<.001		<.001		<.001		<.001		<.001		<.001		<.001		<.001	

[a] All interference subscales scores are for the 6-week follow-up time point except for results presented by time point category.
[b] For categories of age, sex, education, relationship status, and pain distribution, results shown are means (0–10 scale) and standard errors of means at 6 weeks, adjusted for overall pain intensity at 6 week. Models for age, sex, and education are additionally adjusted for pain distribution (the 5 principal components, PC1–PC5, describing the distribution of pain at 6 weeks).
[c] Results shown are means (0–10 scale) and standard errors of means from a repeated measures model with pain interference (subscale or total) at the time point as the dependent variable and overall pain intensity and pain distribution (the 5 principal components, PC1–PC5, describing the distribution of pain) at the time point as independent variables.

their patient's progress should be aware of which disability measures are most likely to be affected by reductions in axial pain. For example, outcomes such as general activity, mood, and normal work would be valuable to assess, but walking ability is less likely to be affected. Similar considerations apply to clinical trials of individuals with post-MVC axial pain. In addition, clinical prediction tools developed to identify those at high risk for persistent post-MVC pain should not focus on neck pain outcomes but rather should examine axial pain more generally, as this pain distribution has the greatest impact on function.

Our findings that individuals with widespread pain after MVC experienced substantially more pain interference than individuals with regional pain is consistent with previous studies [2,5,38] and suggests the importance of pain extent, as well as pain severity, on functional outcomes after MVC. Widespread musculoskeletal pain has been shown to affect working ability [34], life satisfaction, and general health [5,38]. Therefore, individuals with widespread musculoskeletal pain might require more intensive treatment and also have greater potential to benefit from such treatment than individuals with localized pain.

Interestingly, although women reported more pain than men, after adjustment for overall pain intensity and distribution, men reported significantly higher levels of pain interference than women. Although the majority of previous studies suggest that women are more likely to experience disability due to pain than men [17,24,46], a few studies found the opposite: disability was either more directly related to pain in men than in women [21] or was not associated with sex [27]. Of note, the study by Stubbs and coworkers [46] found that the difference in disability between men and women was attenuated when adjusted for pain severity. Interestingly, Hirsh and coworkers [21] found that disability is directly related to pain in men, whereas the effect of pain on disability in women is mediated by negative mood. Consistent with our work, a study by Fejer and colleagues [15], using 2 pain-related disability measures to evaluate the best cutoffs between mild, moderate, and severe neck pain, demonstrated that women had a higher optimal single cutoff for neck pain than men, suggesting that women are more tolerant to pain of similar intensity than men.

In our study, younger participants (18–26 years old) reported less pain interference than participants 27 to 65 years old. Several previous studies have observed a high prevalence of pain interference in older adults [44,50]. A population-based study of adults aged 50 and older with regional pain revealed increased prevalence of pain interference among older individuals [50]. Another study found that among pain clinic patients with chronic pain, patients aged 60 and older reported similar levels of pain intensity and worse physical functioning but better mental health than younger adults with pain [55]. Similarly, advanced age has been associated with self-rated health status after controlling for pain and other sociodemographic factors among individuals 70 years and older [43]. The differences between younger and middle-age or older-age participants observed in our study might be explained by physiologic resilience to the effects of pain in younger adults. For example, it has been shown experimentally that younger adults (age 18–25 years) have more active endogenous pain

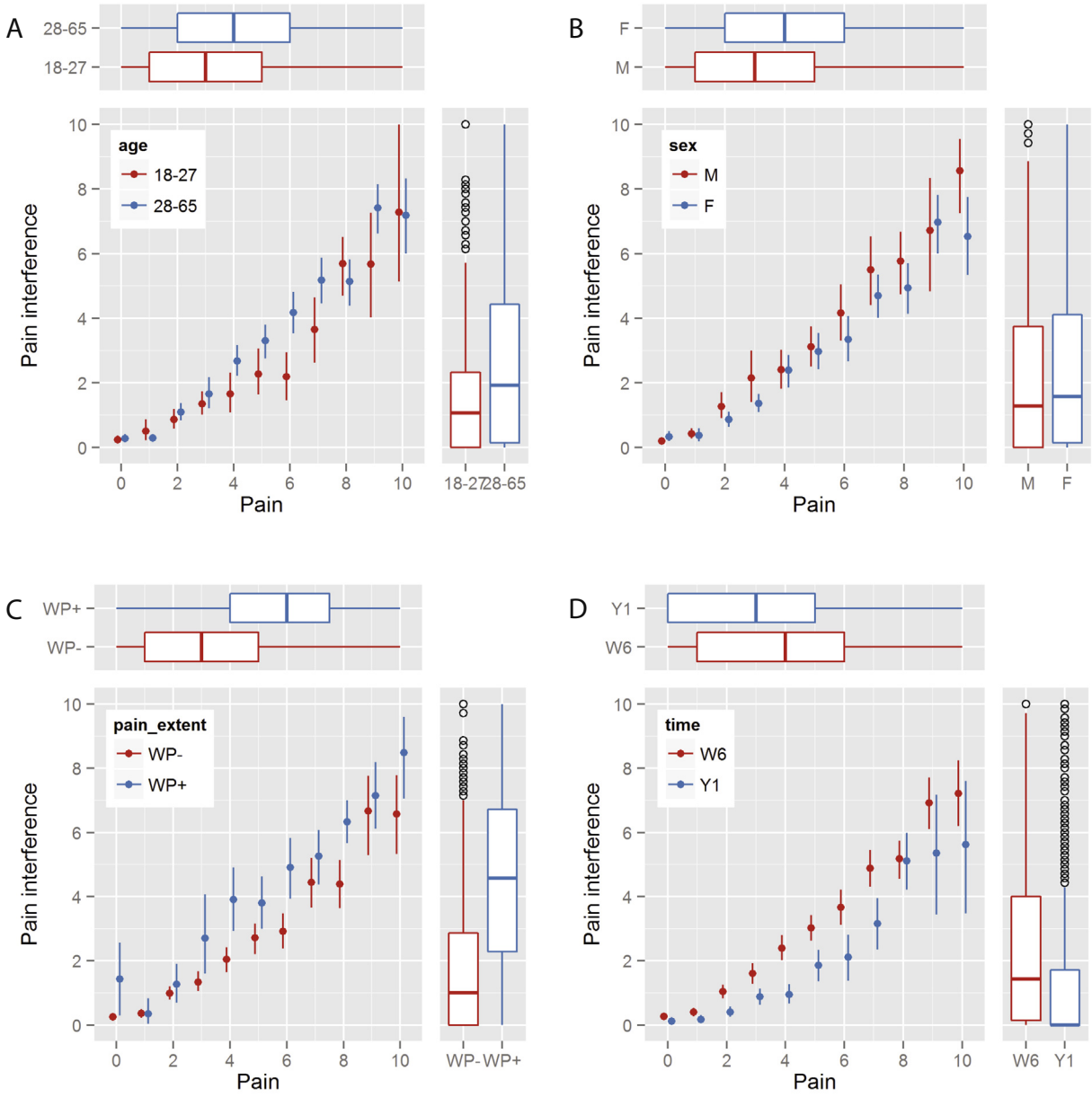


Fig. 4. Association between pain and pain interference stratified by (a) age, (b) sex, (c) widespread pain, and (d) time from trauma. Dots represent mean interference and vertical bars represent bootstrap-derived 95% confidence intervals for interference for each discrete value of the overall pain score. Box plots represent median, lower, upper quartile, and range for pain (horizontal box plots at top) and for pain interference (vertical box plots at right). WP+, widespread pain present; WP−, no widespread pain; W6, week 6; Y1, year 1.

inhibition signaling than older adults [13]. The use of different coping mechanisms and strategies in younger patients might also contribute to this difference [25,30].

Because our study design allowed us to prospectively evaluate pain and pain interference over time after MVC, we were able to assess the effect of time on pain interference. After adjusting for pain intensity and distribution, we found that study participants experienced on average a 38% reduction in pain interference between 6 weeks and 1 year. The observed decrease in pain interference for a given level of pain speaks to the resiliency of individuals experiencing traumatic events and may be explained by the adoption of more effective methods of coping with pain over time, or by other factors. This finding is consistent with observations that quality of life improves over time after other forms of trauma [37,51,53]. This finding is also in agreement with the results by Fejer and colleagues [15], who evaluated the optimal cutoffs for neck pain using 2 measures of pain-related disability and found that the optimal single cutoff is higher for chronic neck pain than for acute and subacute neck pain.

Several limitations should be considered when interpreting our study results. First, the participants in our study were European Americans aged 18 to 65 years of age who presented to the ED for evaluation. The extent of pain after MVC and determinants of widespread pain may differ in other ethnic and racial groups, older adults [40], and individuals who do not come to the ED for evaluation after MVC. In addition, our study did not adjust for factors such as comorbid conditions [12,42], psychological distress [9], expectations of recovery [22], or insurance and litigation [7,33] when evaluating the association between pain patterns and disability. These factors have been shown to predict pain outcomes. However, our goal was to describe cross-sectional associations between pain locations and pain-related disability. We did not attempt to assess the causal relationship between pain location and disability, independent of all other factors. This might a

valuable area of future inquiry. Additionally, our study focused on individuals who were evaluated in the ED and subsequently discharged home, a population that comprises approximately 90% of all patients seen in U.S. EDs after MVC. The pain experiences may differ among those patients experiencing more serious injuries who are admitted to the hospital. Although 99% of study participants had only minor injury (an AIS score of 1), more subtle differences in injury severity were not measured, and such differences may have explained some of the observed variation in pain and pain interference by age, sex, and pain location. Finally, no data were available for the first few weeks after MVC. Knowing the early trajectory of pain and pain-related interference in this population may be important to fully characterize the post-MVC outcomes.

In conclusion, our study results indicate that after controlling for pain severity, axial and widespread pain result in greater pain interference after MVC than nonaxial or more localized pain. Interventions seeking to achieve the greatest functional improvement in post-MVC pain should focus on axial pain or widespread pain because these regions appear to have the greatest influence on disability. In addition, ED-based clinical prediction tools should be developed that are informed by the extensive previous literature on chronic pain risk factors and identify adults at high risk of developing axial pain. Finally, practitioners treating individuals with post-MVC pain disorders and performing serial outcome assessments to monitor their patient's progress should select the disability measures most affected by reductions in their patient's specific pain distribution.

Conflict of interest statement

The authors report no conflict of interest.

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References

[1] Amris K, Waehrens EE, Jespersen A, Bliddal H, Danneskiold-Samsoe B. Observation-based assessment of functional ability in patients with chronic widespread pain: a cross-sectional study. PAIN® 2011;152:2470–6.
[2] Andersson HI, Ejlertsson G, Leden I, Rosenberg C. Characteristics of subjects with chronic pain, in relation to local and widespread pain report. A prospective study of symptoms, clinical findings and blood tests in subgroups of a geographically defined population. Scand J Rheumatol 1996;25:146–54.
[3] Baker SP, O'Neill B, Haddon W, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974;14:187–96.
[4] Berglund A, Alfredsson L, Jensen I, Cassidy JD, Nygren A. The association between exposure to a rear-end collision and future health complaints. J Clin Epidemiol 2001;54:851–6.
[5] Bergman S, Jacobsson LT, Herrstrom P, Petersson IF. Health status as measured by SF-36 reflects changes and predicts outcome in chronic musculoskeletal pain: a 3-year follow up study in the general population. PAIN® 2004;108:115–23.
[6] Birley T, Goebel A. Widespread pain in patients with complex regional pain syndrome. Pain Pract, in press.
[7] Blyth FM, March LM, Nicholas MK, Cousins MJ. Chronic pain, work performance and litigation. PAIN® 2003;103:41–7.
[8] Bortsov AV, Platts-Mills TF, Peak DA, Jones JS, Swor RA, Domeier RM, Lee DC, Rathlev NK, Hendry PL, Fillingim RB, McLean SA. Pain distribution and predictors of widespread pain in the immediate aftermath of motor vehicle collision. Eur J Pain 2013;17:1243–51.
[9] Castro WH, Meyer SJ, Becke ME, Nentwig CG, Hein MF, Ercan BI, Thomann S, Wessels U, Du Chesne AE. No stress—no whiplash? Prevalence of "whiplash" symptoms following exposure to a placebo rear-end collision. Int J Legal Med 2001;114:316–22.
[10] Cleeland CS, Ryan KM. Pain assessment: global use of the brief pain inventory. Ann Acad Med Singapore 1994;23:129–38.
[11] Cote P, Cassidy JD, Carroll L. The Saskatchewan health and back pain survey. The prevalence of neck pain and related disability in Saskatchewan adults. Spine (Phila Pa 1976) 1998;23:1689–98.
[12] Dominick CH, Blyth FM, Nicholas MK. Unpacking the burden: understanding the relationships between chronic pain and comorbidity in the general population. PAIN® 2012;153:293–304.
[13] Edwards RR, Fillingim RB, Ness TJ. Age-related differences in endogenous pain modulation: a comparison of diffuse noxious inhibitory controls in healthy older and younger adults. PAIN® 2003;101:155–65.
[14] Eggermont LH, Bean JF, Guralnik JM, Leveille SG. Comparing pain severity versus pain location in the MOBILIZE Boston study: chronic pain and lower extremity function. J Gerontol A Biol Sci Med Sci 2009;64:763–70.
[15] Fejer R, Jordan A, Hartvigsen J. Categorising the severity of neck pain: establishment of cut-points for use in clinical and epidemiological research. PAIN® 2005;119:176–82.
[16] Freeman MD, Croft AC, Rossignol AM, Weaver DS, Reiser M. A review and methodologic critique of the literature refuting whiplash syndrome. Spine (Phila Pa 1976) 1999;24:86–96.
[17] Greenspan JD, Craft RM, LeResche L, Arendt-Nielsen L, Berkley KJ, Fillingim RB, Gold MS, Holdcroft A, Lautenbacher S, Mayer EA, Mogil JS, Murphy AZ, Traub RJ. Studying sex and gender differences in pain and analgesia: a consensus report. PAIN® 2007;132:S26–45.
[18] Gronblad M, Jarvinen E, Airaksinen O, Ruuskanen M, Hamalainen H, Kouri JP. Relationship of subjective disability with pain intensity, pain duration, pain location, and work-related factors in nonoperated patients with chronic low back pain. Clin J Pain 1996;12:194–200.
[19] Hair JF, Anderson RE, Tatham RL, Black WC, editors. Multivariate data analysis. Upper Saddle River, NJ: Prentice-Hall; 1998.
[20] Hartling L, Brison RJ, Ardern C, Pickett W. Prognostic value of the Quebec classification of whiplash-associated disorders. Spine (Phila Pa 1976) 2001;26:36–41.
[21] Hirsh AT, Waxenberg LB, Atchison JW, Gremillion HA, Robinson ME. Evidence for sex differences in the relationships of pain, mood, and disability. J Pain 2006;7:592–601.
[22] Holm LW, Carroll LJ, Cassidy JD, Skillgate E, Ahlbom A. Expectations for recovery important in the prognosis of whiplash injuries. PLoS Med 2008;5:e105.
[23] Jordan KP, Sim J, Moore A, Bernard M, Richardson J. Distinctiveness of long-term pain that does not interfere with life: an observational cohort study. Eur J Pain 2012;16:1185–94.
[24] Keefe FJ, Lefebvre JC, Egert JR, Affleck G, Sullivan MJ, Caldwell DS. The relationship of gender to pain, pain behavior, and disability in osteoarthritis patients: the role of catastrophizing. PAIN® 2000;87:325–34.
[25] Keefe FJ, Williams DA. A comparison of coping strategies in chronic pain patients in different age groups. J Gerontol 1990;45:P161–5.
[26] Keller S, Bann CM, Dodd SL, Schein J, Mendoza TR, Cleeland CS. Validity of the brief pain inventory for use in documenting the outcomes of patients with noncancer pain. Clin J Pain 2004;20:309–18.
[27] Keogh E, McCracken LM, Eccleston C. Gender moderates the association between depression and disability in chronic pain patients. Eur J Pain 2006;10:413–22.
[28] Krafft M, Kullgren A, Tingvall C, Bostrom O, Fredriksson R. How crash severity in rear impacts influences short- and long-term consequences to the neck. Accid Anal Prev 2000;32:187–95.
[29] Lamb SE, Gates S, Williams MA, Williamson EM, Mt-Isa S, Withers EJ, Castelnuovo E, Smith J, Ashby D, Cooke MW, Petrou S, Underwood MR. Emergency department treatments and physiotherapy for acute whiplash: a pragmatic, two-step, randomised controlled trial. Lancet 2013;381:546–56.
[30] Lefebvre JC, Lester N, Keefe FJ. Pain in young adults. II. The use and perceived effectiveness of pain-coping strategies. Clin J Pain 1995;11:36–44.
[31] Linton SJ. A review of psychological risk factors in back and neck pain. Spine (Phila Pa 1976) 2000;25:1148–56.
[32] McLean SA. The potential contribution of stress systems to the transition to chronic whiplash-associated disorders. Spine 2011;36:S226–32.
[33] McLean SA, Ulirsch JC, Slade GD, Soward AC, Swor RA, Peak DA, Jones JS, Rathlev NK, Lee DC, Domeier RM, Hendry PL, Bortsov AV, Bair E. Incidence and predictors of neck and widespread pain after motor vehicle collision among US litigants and nonlitigants. PAIN® 2014;155:309–21.
[34] Miranda H, Kaila-Kangas L, Heliovaara M, Leino-Arjas P, Haukka E, Liira J, Viikari-Juntura E. Musculoskeletal pain at multiple sites and its effects on work ability in a general working population. Occup Environ Med 2010;67:449–55.
[35] Miro J, Gertz KJ, Carter GT, Jensen MP. Pain location and functioning in persons with spinal cord injury. PM R, in press.
[36] Niska R, Bhuiya F, Xu J. National hospital ambulatory medical care survey: 2007 emergency department summary. Natl Health Stat Report 2010;26:1–31.
[37] Oster C, Willebrand M, Ekselius L. Health-related quality of life 2 years to 7 years after burn injury. J Trauma 2011;71:1435–41.
[38] Peolsson M, Borsbo B, Gerdle B. Generalized pain is associated with more negative consequences than local or regional pain: a study of chronic whiplash-associated disorders. J Rehabil Med 2007;39:260–8.
[39] Platts-Mills TF, Ballina L, Bortsov AV, Soward A, Swor RA, Jones JS, Lee DC, Peak DA, Domeier RM, Rathlev NK, Hendry PL, McLean SA. Using emergency

department-based inception cohorts to determine genetic characteristics associated with long term patient outcomes after motor vehicle collision: methodology of the CRASH study. BMC Emerg Med 2011;11:14.
[40] Platts-Mills TF, Burke GF, Lee YM, Swor RA, Zaleski EZ, Clauw DJ, McLean SA. Pain and interference of pain with function and mood in elderly adults involved in a motor vehicle collision: a pilot study. Exp Aging Res 2012;38:330–43.
[41] Platts-Mills TF, Hunold KM, Esserman DA, Sloane PD, McLean SA. Motor vehicle collision-related emergency department visits by older adults in the United States. Acad Emerg Med 2012;19:821–7.
[42] Rethelyi JM, Berghammer R, Kopp MS. Comorbidity of pain-associated disability and depressive symptoms in connection with sociodemographic variables: results from a cross-sectional epidemiological survey in Hungary. PAIN® 2001;93:115–21.
[43] Reyes-Gibby CC, Aday L, Cleeland C. Impact of pain on self-rated health in the community-dwelling older adults. PAIN® 2002;95:75–82.
[44] Scudds RJ, Ostbye T. Pain and pain-related interference with function in older Canadians: the Canadian study of health and aging. Disabil Rehabil 2001;23:654–64.
[45] Sterling M, Hendrikz J, Kenardy J, Kristjansson E, Dumas JP, Niere K, Cote J, Deserres S, Rivest K, Jull G. Assessment and validation of prognostic models for poor functional recovery 12 months after whiplash injury: a multicentre inception cohort study. PAIN® 2012;153:1727–34.
[46] Stubbs D, Krebs E, Bair M, Damush T, Wu J, Sutherland J, Kroenke K. Sex differences in pain and pain-related disability among primary care patients with chronic musculoskeletal pain. Pain Med 2010;11:232–9.
[47] Tabachnick BG, Fidell LS. Using multivariate statistics. 5th ed. New York: Allyn & Bacon; 2006.
[48] Tan G, Jensen MP, Thornby JI, Shanti BF. Validation of the brief pain inventory for chronic nonmalignant pain. J Pain 2004;5:133–7.
[49] Tanskanen A, Hintikka J, Honkalampi K, Haatainen K, Koivumaa-Honkanen H, Viinamaki H. Impact of multiple traumatic experiences on the persistence of depressive symptoms—a population-based study. Nord J Psychiatry 2004;58:459–64.
[50] Thomas E, Peat G, Harris L, Wilkie R, Croft PR. The prevalence of pain and pain interference in a general population of older adults: cross-sectional findings from the North Staffordshire Osteoarthritis Project (NorStOP). PAIN® 2004;110:361–8.
[51] Toien K, Bredal IS, Skogstad L, Myhren H, Ekeberg O. Health related quality of life in trauma patients. Data from a one-year follow up study compared with the general population. Scand J Trauma Resusc Emerg Med 2011;19:22.
[52] Webb R, Brammah T, Lunt M, Urwin M, Allison T, Symmons D. Prevalence and predictors of intense, chronic, and disabling neck and back pain in the UK general population. Spine (Phila Pa 1976) 2003;28:1195–202.
[53] Westgren N, Levi R. Quality of life and traumatic spinal cord injury. Arch Phys Med Rehabil 1998;79:1433–9.
[54] Wickham H. Ggplot2: elegant graphics for data analysis. New York: Springer; 2009.
[55] Wittink HM, Rogers WH, Lipman AG, McCarberg BH, Ashburn MA, Oderda GM, Carr DB. Older and younger adults in pain management programs in the United States: differences and similarities. Pain Med 2006;7:151–63.
[56] Wolfe F. Pain extent and diagnosis: development and validation of the regional pain scale in 12,799 patients with rheumatic disease. J Rheumatol 2003;30:369–78.
[57] Wolfe F, Smythe HA, Yunus MB, Bennett RM, Bombardier C, Goldenberg DL, Tugwell P, Campbell SM, Abeles M, Clark P, Fam AG, Farber SJ, Feichtner JJ, Franklin CM, Gatter RA, Hamaty D, Lessard J, Lichtbroun AS, Masi AT, Mccain GA, Reynolds WJ, Romano TJ, Russell IJ, Sheon RP. The American College of Rheumatology 1990 Criteria for the Classification of Fibromyalgia, Report of the Multicenter Criteria Committee. Arthritis Rheum 1990;33:160–72.
[58] Yadla S, Ratliff JK, Harrop JS. Whiplash: diagnosis, treatment, and associated injuries. Curr Rev Musculoskelet Med 2008;1:65–8.
[59] Yeomans KA, Golder PA. The Guttman-Kaiser criterion as a predictor of the number of common factors. J R Stat Soc Ser D Stat 1982;31:221–9.