Preventive Medicine 164 (2022) 107275

Contents lists available at ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

A serial cross-sectional study of trends and predictors of prescription controlled substance-related traumatic injury

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A R T I C L E I N F O

Keywords:
Controlled substances
Prescriptions
Wounds and injuries
Risk factors

A B S T R A C T

Pre-injury drug use is a key contributor to traumatic injury. However, limited research has examined trends and predictors of controlled substance-related trauma. The present study aims to provide better clarity on the specific role of prescription-controlled substances (PCS) in traumatic injury events.

The data source was the American College of Surgeons National Trauma Data Bank. Trends by injury mechanism and intent for patients with PCS and no-confirmed substances were compared from 2007 to 2014. Logistic regression models were also performed to examine the association between substance use and injury mechanism and intent for data across the study period.

Of 405,334 trauma patients, 328,623 (81.1%) had no-confirmed substances and 76,711 (18.9%) had PCS detected. The majority of events in the PCS and no-confirmed substance groups were classified as unintentional. Motor vehicle traffic (MVT), falls, other transport, and cut/pierce injuries accounted for approximately 80% of all injuries. From 2007 to 2014, the proportion of injuries with PCS increased for all injury mechanisms and injury intents. The injury mechanisms of fire/burn, firearm, machinery, poisoning, and other transport were significantly more likely to have PCS relative to MVT injuries. For injury intent, self-harm was more likely to have a toxicology test positive for PCS, while assault was less likely to have a toxicology test positive for PCS compared to unintentional injuries.

PCS-related traumatic injuries increased significantly over time and across injury mechanisms and intents. These findings can be used to inform prescribing and understand risk factors to reduce the likelihood of PCS-related traumatic injury.

1. Introduction

Traumatic injury is the leading cause of admission to emergency departments in the United States (Cowperthwaite and Burnett, 2011). Pre-injury drug use has been found to be a key contributor to the incidence of traumatic injury (Cowperthwaite and Burnett, 2011; Cheng, 2016), with an estimated 40% to 50% of trauma patients reporting pre-injury drug use (Cowperthwaite and Burnett, 2011; Zeller, 2007; Dunham and Chirichella, 2012). In particular, use of controlled substances is prominent among patients admitted for trauma (Cheng, 2016). Pre-injury use of controlled substances may increase the likelihood of sustaining an injury, and it may also complicate treatment because of a substance's stimulant or depressant effects (Cheng, 2016).

Limited research has examined trends and patient-level predictors of controlled substance-related trauma. Of the studies that have been conducted, most have focused on single trauma centers and examined the effects of specific substances, such as opioids or benzodiazepines (Cowperthwaite and Burnett, 2011; Cheng, 2016; Pandya et al., 2015; Cannon et al., 2014; Soderstrom et al., 2001). Patient and injury characteristics associated with controlled substance-related trauma differ

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https://doi.org/10.1016/j.ypmed.2022.107275
Received 19 April 2022; Received in revised form 12 August 2022; Accepted 18 September 2022
Available online 22 September 2022

and are inconsistent between studies. Multiple studies found those that tested positive for controlled substances were more likely to be female and older in age (Pandya et al., 2015; Cannon et al., 2014), although elsewhere it has been shown that younger males were more likely to have substances detected (Soderstrom et al., 2001). The injury mechanism has also been found to differ between patients that were positive for controlled substances compared to those with negative results, with a significantly higher risk of fall and violence-related injuries, and lower likelihood of firearm and motor vehicle crash injuries (Pandya et al., 2015; Soderstrom et al., 2001). However, other research found no differences in injury mechanisms between those who tested positive for controlled substances versus those who did not (Cannon et al., 2014). Part of the inconsistency in findings is likely as a result of the various controlled substance use definitions that have been utilized, ranging from any drug use, controlled substance use, illegal substance use, prescription drug use or combinations of these.

Past and present research on this topic also sits within the context of the opioid epidemic that began sweeping the United States in the early 2000's. A key contributor to the earlier phases of the opioid epidemic was inappropriate prescribing; from 1999 to 2020 > 263,000 individuals have died from an overdose involving prescription opioids (Guy et al., 2017). National attention to these behaviors led to the leveling off and gradual decline of opioid prescribing since 2012, however, prescribing rates are still over three times higher than they were in 2000 (Guy et al., 2017). Other measures of prescription opioid use have worsened, such as an increase in the number of days that opioids are prescribed, which results in unused and leftover medication. Excess pills are a known contributor to opioid misuse and diversion (National Center for Injury Prevention and Control, 2018). Although prescribing practices overall have decreased since 2012, the Centers for Disease Control and Prevention (CDC) estimated that almost 58 opioid prescriptions are written per 100 persons (National Center for Injury Prevention and Control, 2018). There is clearly still a need to inform prescribers, pharmacists and healthcare personnel of the adverse health outcomes associated with use of controlled substances.

The current study aims to take advantage of a wealth of information and sizable, nationally representative study population from the National Trauma Data Bank (NTDB) to examine the role of prescription controlled substances (PCS) in traumatic injuries. Specifically, this study will: (1) determine the prevalence of pre-injury PCS from 2007 to 2014; (2) describe the trends and changes in injury mechanism and injury intent for PCS-related trauma across the study period; and (3) characterize predictors of PCS-related trauma as compared to trauma not involving substance use. The study will examine in detail patient, temporal, demographic, injury intent, and injury mechanism factors that are associated with a positive toxicology test for PCS upon admission. The present study aims to provide better clarity on the specific role of PCS in traumatic injury events.

2. Methods

2.1. Data source

The data source for this study was the American College of Surgeons (ACS) NTDB, which is the largest trauma registry in the United States (Haider et al., 2012). The NTDB includes patient and hospital data on traumatic injuries and clinical outcomes from >700 trauma centers.

This study was approved by the University of Minnesota Institutional Review Board (STUDY00001489). The need for individual patient consent was waived because all data used in this study were already de-identified in the NTDB.

2.2. Participants

Patient-level data were obtained from the NTDB from January 1, 2007 through December 31, 2014. The choice of the study period was determined by the data quality of the NTDB. Prior to 2007, there were important data quality issues that made it not suitable for this research. This study focused on the most recently available data at the time of analysis because the NTDB datasets lag at least two years behind. The inclusion criteria were as follows (See Fig. 1.):

- Age ≥ 16 years
- At least one valid International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) trauma code (ICD-9-CM code range: 800–959.9)
- Admission to a U.S. trauma center for definitive care
- Patients with toxicology testing completed. This does not include alcohol testing alone as that is captured separately in the NTDB.
- Patients with PCS or no-confirmed substances identified from toxicology testing. PCS is defined as substances present on toxicology testing that were prescribed to the patient.

Exclusion criteria were as follows:

- Patients with no signs of life at initial evaluation (i.e., emergency department (ED) systolic blood pressure (SBP) = 0, pulse = 0, Glasgow Coma Scale (GCS) score = 3) (Calland et al., 2012)
- Patients transferred for definitive care
- Participants with illegal substances or combination of PCS and illegal substances. We excluded patients with illegal substances because our

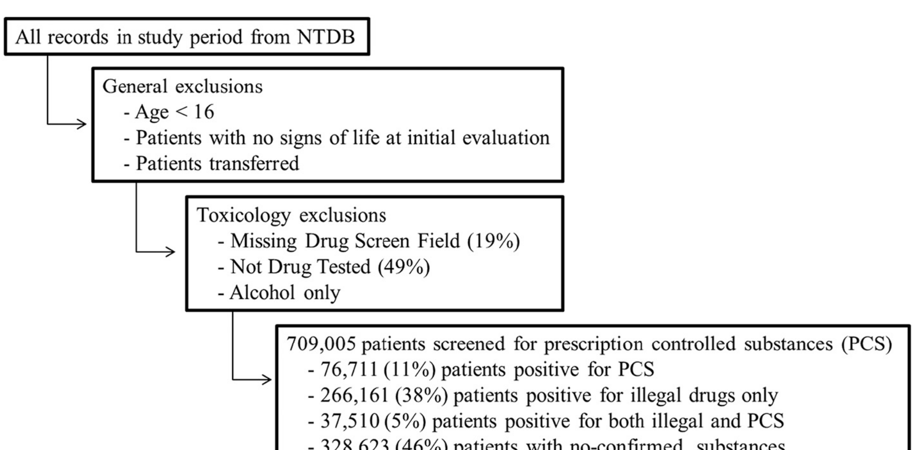

Fig. 1. Study diagram detailing selection of patients in 2007–2014 Trauma Databank (NTDB).

objective was to examine the relationship between PCS and traumatic injury.

2.3. Measures

Substance use was identified in the NTDB, and refers to drug use by the patient that was confirmed by a test, and does not include drugs used in medical treatment (ACS NTDB National Trauma Data Standard: Data Dictionary 2016 Admissions [Internet], 2016). Available response options include patient was not tested, patient with no-confirmed substances, patient with PCS, and patient with illegal substances. Over the study period, about half (49%) of patients reported in the NTDB were not tested or screened for drug use. One quarter (24%) of patients had a drug test performed, while for the remaining patients (27%) it was not known or not reported if drug testing occurred. This study was restricted to patients with drug testing performed and either PCS or no-confirmed substances identified.

We used the CDC, National Center for Health Statistics ICD-9-CM framework for external-cause-of-injury codes (Centers for Disease Control and Prevention, 2011). This framework was applied to the ICD-9-CM trauma diagnosis codes in the NTDB. These codes indicate two characteristics of the traumatic injury that were used in this analysis: injury mechanism/cause (i.e., the process by which the injury occurred); and injury manner/intent (i.e., whether an injury was caused by an act carried out on purpose by oneself or another person, with the goal of injuring).

Within the ICD-9-CM framework, multiple motor vehicle and transport-related injury mechanism categories are used, including motor vehicle traffic (MVT), pedal cyclist, pedestrian, and other transport (Centers for Disease Control and Prevention, 1997). For clarity when interpreting the results, further detail is presented here that distinguishes these categories (Centers for Disease Control and Prevention, 1997). The MVT category includes all injuries resulting from automobiles, vans, trucks, motorcycles, and other motorized cycles traveling on public roads or highways at the time of injury. The pedal cyclist category includes all injuries among pedal cyclists not involving MVT incidents; including persons hit by a train or by a motor vehicle while not in traffic; hit by other means of transport; and injured by a collision with another pedal cycle. This category is intended to include only injuries to pedal cycle riders, not all injuries involving a pedal cycle. The pedestrian category includes injuries among pedestrians hit by a train, a motor vehicle where the collision did not occur in traffic, or another means of transportation. This category often involves trains and not motor vehicles. The other transport category includes injuries associated with various other means of transportation: railway, off-road and other motor vehicles not in traffic, other surface transport, water, and aircraft. There is also an "other" injury mechanism category. This is comprised of 1) other unspecified injuries that are not assigned to specific categories in the external-cause-of-injury framework, 2) injuries where no specific external-cause-of-injury code exists, or 3) where the injury mechanism was not reported in the hospital record.

We obtained additional information regarding patient and injury characteristics from the NTDB that were included in the analysis. Patient characteristics included age (at time of ED visit), gender, and race and ethnicity. Age was categorized as 16–25, 26–45, 46–65, 66–75, and >75 years. Race and ethnicity were categorized as white, Black, Hispanic or Latino, Asian, and Other Race. The Other Race group included American Indian (1%), Native Hawaiian or Pacific Islander (<1%), and Other Race (13%), which is where a patients' self-reported race was not captured in the five specific race categories defined in the NTDB.

2.4. Statistical analyses

First, the number and proportion of trauma patients with PCS and no-confirmed substance for each injury mechanism and injury intent were calculated by year. This was done to describe how the proportion of trauma patients for the two substance categories changed from 2007 to 2014. Simple logistic regression models with substance use and year were performed for each injury mechanism and injury intent to examine changes in odds ratios for PCS over the study period. A parameter estimate for year with $p \leq 0.05$ indicated a statistically significant trend in the odds of PCS.

Second, logistic regression models describing the association between PCS and injury mechanism and injury intent, respectively, were performed with data across the study period. The primary outcome was substance use (i.e., PCS versus no-confirmed substances). The primary exposure was injury mechanism or injury intent. The models further controlled for year (i.e., year of admission date), age, sex, and race, as well as injury location (i.e., the place, site, or location of the injury event), work relatedness (i.e., indicated whether the injury occurred during paid employment), emergency medical services (EMS) response time (i.e., the elapsed time from EMS dispatch to hospital arrival), trauma level (i.e., ACS trauma verification level of the hospital), number of hospital beds (i.e., the number of beds for adult patients), and hospital transfer (i.e., indicated if the patient transferred from one acute care facility to another during the course of the visit). Alpha was set at $p \leq 0.05$, using two-tailed tests for significance. For all statistical analyses, we used Stata MP, version 15 (StataCorp, College Station, TX).

3. Results

From 2007 to 2014, a total of 405,334 trauma patients were admitted to hospitals participating in the NTDB that met the study inclusion criteria. Of these, 328,623 (81.1%) trauma patients had no-confirmed substances detected, while 76,711 (18.9%) patients had a toxicology test detect PCS. The majority of events in the PCS and no-confirmed substance groups were classified as unintentional (No-confirmed substance: $N = 276{,}321$ (84.2%); PCS: $N = 64{,}773$ (84.6%)), followed by assault (No-confirmed substance: $N = 41{,}465$ (12.6%); PCS: $N = 8171$ (10.7%)), and self-harm (No-confirmed substance: $N = 8497$ (2.6%); PCS: $N = 3103$ (4.1%)). The leading injury mechanisms were common between the two groups, with motor vehicle traffic (MVT) (No-confirmed substance: $N = 144{,}686$ (44.1%); PCS: $N = 33{,}345$ (43.6%)), falls (No-confirmed substance: $N = 86{,}856$ (26.5%); PCS: $N = 19{,}225$ (25.1%)), other transport (No-confirmed substance: $N = 19{,}286$ (5.9%); PCS: $N = 5568$ (7.3%)), and cut/pierce (No-confirmed substance: $N = 15{,}788$ (4.8%); PCS: $N = 3558$ (4.7%)) accounting for approximately 80% of all injuries (Table 1).

Changes from 2007 to 2014 in the proportion of trauma patients with no-confirmed substances and PCS by injury mechanism are shown in Table 2a. From 2007 to 2014, the proportion of injuries with PCS increased for all injury mechanisms. Notably, for PCS, fall injuries increased from 5% to 16% ($p < 0.0001$), fire/burn injuries increased from 3% to 21% ($p < 0.0001$), machinery injuries increased from 4% to 20% ($p < 0.0001$), MVT injuries increased from 4% to 15% ($p < 0.0001$), pedestrian injuries increased from 6% to 17% ($p < 0.0001$), and other transport injuries increased from 6% to 16% ($p < 0.0001$). The proportion of injuries with no-confirmed substances remained stable across injury mechanisms from 2007 to 2014.

Changes in the proportion of trauma patients with no-confirmed substances and PCS by injury intent from 2007 to 2014 are shown in Table 2b. The proportion of injuries with PCS notably increased for all injury intents: unintentional injuries with PCS increased from 4% to 15% ($p < 0.0001$), self-harm injuries increased from 6% to 18% ($p < 0.0001$), assault injuries increased from 3% to 9% ($p < 0.0001$), and undetermined injuries increased from 6% to 11% ($p < 0.0001$). The proportion of injuries with no-confirmed substances remained relatively stable across injury intents over the study period.

Results from the logistic regression model show injury mechanisms differed between patients with PCS as compared to those with no-

Table 1
Descriptive statistics and adjusted odds ratios for prescription controlled substances compared to no-confirmed substances detected on toxicology for trauma injury circumstances and patient characteristics, National Trauma Data Bank, 2007–2014.

Injury mechanism	Total N (%)	PCS N (%)	No-confirmed substances N (%)	Odds ratio	95% CI	
MVT	307,434 (42.4)	33,345 (43.6)	144,686 (44.1)	Ref.		
Cut/Pierce	42,795 (6.0)	3558 (4.7)	15,788 (4.8)	1.03	0.96	1.13
Drown	386 (0.1)	41 (0.1)	186 (0.1)	1.11	0.72	1.72
Fall	158,340 (22.4)	19,225 (25.1)	86,856 (26.5)	1.00	0.96	1.05
Fire/burn	11,832 (1.7)	2120 (2.8)	4007 (1.2)	2.30	2.11	2.52
Firearm	43,812 (6.2)	3678 (4.8)	13,920 (4.2)	1.28	1.18	1.39
Machinery	3900 (0.6)	525 (0.7)	2197 (0.7)	1.16	1.01	1.32
Pedal cyclist	10,052 (1.5)	963 (1.3)	5733 (1.8)	0.76	0.69	0.83
Pedestrian	2380 (0.3)	244 (0.3)	1119 (0.3)	1.02	0.85	1.21
Other transport	41,347 (5.8)	5568 (7.3)	19,286 (5.9)	1.11	1.06	1.17
Natural	2526 (0.4)	258 (0.3)	1254 (0.4)	0.96	0.79	1.17
Poison	468 (0.1)	97 (0.1)	169 (0.1)	1.75	1.25	2.47
Struck by	57,065 (8.1)	4469 (5.8)	23,081 (7.0)	0.98	0.91	1.05
Suffocation	1320 (0.2)	187 (0.2)	473 (0.1)	1.19	0.95	1.48
Other	24,071 (3.4)	2297 (3.0)	9494 (2.9)	1.07	0.99	1.16
Total	708,456 (100.0)	76,600 (10.8)	328,383 (46.4)			
Injury intent	Total N (%)	PCS N (%)	No-confirmed substances N (%)	Odds ratio	95% CI	
Unintentional	560,230 (79.1)	64,773 (84.6)	276,321 (84.2)	Ref.		
Self-harm	21,470 (3.0)	3103 (4.1)	8497 (2.6)	1.34	1.25	1.45
Assault	120,324 (17.0)	8171 (10.7)	41,465 (12.6)	0.90	0.84	0.96
Undetermined	4176 (0.6)	380 (0.5)	1444 (0.4)	1.07	0.90	1.26
Other (legal intervention/ war)	2078 (0.3)	136 (0.2)	583 (0.2)	0.97	0.76	1.24
Total	708,278 (100.0)	76,563 (10.8)	328,310 (46.4)			
Age category	Total N (%)	PCS N (%)	No-confirmed substances N (%)	Odds ratio	95% CI	
16–25	179,478 (25.4)	15,797 (20.6)	75,588 (23.0)	Ref.		
26–45	249,463 (35.2)	25,647 (33.4)	100,413 (30.6)	1.17	1.14	1.21
46–65	194,490 (27.5)	24,551 (32.0)	93,747 (28.5)	1.14	1.11	1.18
66–75	39,986 (5.7)	5425 (7.1)	26,239 (8.0)	0.86	0.82	0.89
>75	44,477 (6.3)	5285 (6.9)	32,598 (9.9)	0.65	0.62	0.68
Sex	Total N (%)	PCS N (%)	No-confirmed substances N (%)	Odds ratio	95% CI	
Female	508,532 (71.8)	51,907 (67.7)	226,618 (69.0)	Ref.		
Male	200,084 (28.2)	24,783 (32.3)	101,865 (31.0)	0.91	0.89	0.93
Race	Total N (%)	PCS N (%)	No-confirmed substances N (%)	Odds ratio	95% CI	
White	428,464 (62.3)	54,191 (72.1)	206,084 (64.6)	Ref.		
Black	115,536 (16.8)	8385 (11.2)	42,854 (13.4)	0.77	0.75	0.80
Hispanic	96,571 (14.0)	9107 (12.1)	45,040 (14.1)	0.91	0.88	0.94
Asian	13,580 (2.0)	1277 (1.7)	8590 (2.7)	0.71	0.66	0.76
Other	33,648 (4.9)	2256 (3.0)	16,361 (5.1)	0.54	0.51	0.57

Note: Model additionally controlled for injury location, work relatedness, emergency medical services response, treating facility factors, year, and hospital transfer.

confirmed substances. The injury mechanisms of fire/burn (OR = 2.30, 95% CI = 2.11–2.52), firearm (OR = 1.28, CI = 1.18–1.39), machinery (OR = 1.16, 95% CI = 1.01–1.32), poisoning (OR = 1.75, 95% CI = 1.25–2.47), and other transport (OR = 1.11, 95% CI = 1.06–1.17) were significantly more likely to have PCS relative to the injury mechanism of MVT. Pedal cyclist (OR = 0.76, 95% CI = 0.69–0.83) was the only injury mechanism less likely to have PCS relative to the injury mechanism of MVT. Falls, the second most common injury mechanism, did not have increased odds of PCS relative to MVT injuries (OR = 1.00, 95% CI = 0.96–1.05). For injury intent, self-harm was 34% (OR = 1.34, 95% CI = 1.25–1.45) more likely to have a toxicology test positive for PCS, while assault intent was 10% (OR = 0.90, 95% CI = 0.84–0.96) less likely to have a toxicology test positive for PCS compared to unintentional injuries. The predicted probabilities for PCS-related traumatic injury are displayed in Fig. 2 for injury mechanism and Fig. 3 for injury intent. These estimates are calculated from the logistic regression models, providing predicted probabilities for PCS-related traumatic injury for each injury mechanism and injury intent.

Injured individuals 26 to 45 years (OR = 1.17, 95% CI = 1.14–1.21) and 46 to 65 years (OR = 1.14, 95% CI = 1.11–1.18) were more likely to have PCS detected, while those 66–75 years (OR = 0.86, 95% CI = 0.82–0.89) and 75 years and older (OR = 0.65, 95% CI = 0.62–0.68) were less likely to have PCS detected relative to individuals 16–26 years. Injured males were less likely than females (OR = 0.91, 95% CI = 0.89–0.93), and Black (OR = 0.77, 95% CI = 0.75–0.80), Hispanic (OR = 0.91, 95% CI = 0.88–0.94), Asian (OR = 0.71, 95% CI = 0.66–0.76), and Other Races (OR = 0.54, 95% CI = 0.51–0.57) were less likely to have PCS detected relative to whites (Table 1).

4. Discussion

Pre-injury drug use is a key contributor to traumatic injuries and controlled substance use is prominent among patients admitted for trauma. Estimates find 40%–50% of trauma patients have a toxicology test positive for controlled substances, which may also complicate hospital treatment due to the depressant or stimulant effects (Cowperthwaite and Burnett, 2011; Zeller, 2007; Dunham and Chirichella, 2012). In recognition, the ACS Committee on Trauma deem drug and alcohol screening "essential" or "desirable" for all patients on admission to level I, II, or III trauma centers to inform clinical care (Soderstrom et al., 1994). This study examined patient and injury characteristics

Table 2a
Number and proportion of visits for prescription-controlled substances and no-confirmed substances by injury mechanism, National Trauma Data Bank, 2007–2014.

Year		2007	2008	2009	2010	2011	2012	2013	2014	*p*-value
	No-confirmed substances	23,226	42,844	43,721	44,707	41,186	40,690	46,821	45,188	<0.0001
		45.4%	48.8%	47.2%	46.7%	44.9%	43.5%	47.4%	46.6%	
	PCS	2103	7675	9628	10,332	9509	11,696	11,854	13,803	
		4.1%	8.7%	10.4%	10.8%	10.4%	12.5%	12.0%	14.2%	
All mechanisms	Total	51,171	87,867	92,576	95,789	91,673	93,657	98,925	97,347	
	No-confirmed substances	11,015	19,765	19,612	20,128	18,400	17,646	19,579	18,541	<0.0001
		46.1%	49.7%	48.4%	48.4%	46.8%	43.7%	46.9%	46.1%	
	PCS	975	3537	4352	4369	4095	5126	5061	5830	
		4.1%	8.9%	10.7%	10.5%	10.4%	12.7%	12.1%	14.5%	
MVT	Total	23,882	39,807	40,522	41,599	39,343	40,336	41,749	40,196	
	No-confirmed substances	5109	9942	10,509	10,948	11,037	11,037	14,017	14,257	<0.0001
		54.6%	57.2%	55.7%	53.3%	53.2%	51.8%	57.0%	55.9%	
	PCS	453	1565	1993	2595	2398	2913	3269	4039	
		4.8%	9.0%	10.6%	12.6%	11.6%	13.7%	13.3%	15.8%	
Fall	Total	9357	17,394	18,864	20,524	20,760	21,310	24,609	25,522	
	No-confirmed substances	1622	3228	3350	3226	2843	2787	3121	2904	<0.0001
		38.1%	43.8%	42.8%	41.9%	38.4%	37.7%	40.6%	39.2%	
	PCS	127	474	591	624	534	659	655	805	
		3.0%	6.4%	7.6%	8.1%	7.2%	8.9%	8.5%	10.9%	
Struck by	Total	4261	7372	7824	7705	7403	7388	7695	7417	
	No-confirmed substances	1095	1958	1932	1870	1590	1750	1982	1743	<0.0001
		31.8%	35.8%	32.3%	31.8%	28.4%	29.9%	33.4%	31.0%	
	PCS	117	386	487	519	460	526	576	607	
		3.4%	7.0%	8.1%	8.8%	8.2%	9.0%	9.7%	10.8%	
Firearm	Total	3442	5476	5990	5884	5589	5859	5941	5631	
	No-confirmed substances	1091	2216	2325	2215	1856	1936	2166	1983	<0.0001
		36.6%	40.3%	38.6%	37.7%	34.2%	33.9%	37.7%	35.8%	
	PCS	95	366	538	487	406	524	543	599	
		3.2%	6.7%	8.9%	8.3%	7.5%	9.2%	9.5%	10.8%	
Cut/Pierce	Total	2978	5492	6021	5868	5434	5717	5745	5540	
	No-confirmed substances	670	1153	1213	1308	1214	1238	1354	1344	<0.0001
		38.8%	40.8%	38.4%	39.6%	37.8%	37.6%	41.3%	41.0%	
	PCS	55	222	300	325	310	378	329	378	
		3.2%	7.9%	9.5%	9.8%	9.7%	11.5%	10.0%	11.5%	
Other	Total	1729	2826	3159	3304	3209	3291	3275	3278	
	No-confirmed substances	1585	2589	2739	2815	2401	2371	2414	2372	<0.0001
		46.2%	47.8%	46.8%	47.3%	45.3%	45.3%	46.7%	47.4%	
	PCS	203	707	822	776	707	827	744	782	
		5.9%	13.1%	14.0%	13.0%	13.3%	15.8%	14.4%	15.6%	
Other transport	Total	3429	5416	5856	5954	5296	5230	5165	5001	
	No-confirmed substances	313	493	454	491	524	560	578	594	<0.0001
		43.2%	36.1%	30.7%	27.3%	29.3%	33.3%	38.5%	39.8%	
	PCS	20	191	265	339	307	378	311	309	
		2.8%	14.0%	17.9%	18.9%	17.2%	22.5%	20.7%	20.7%	
Fire/burn	Total	725	1366	1481	1797	1787	1681	1502	1493	
	No-confirmed substances	289	779	910	936	648	674	757	740	<0.0001
		50.9%	61.8%	62.7%	59.6%	47.2%	49.6%	50.9%	50.9%	
	PCS	22	84	118	137	128	133	146	195	
		3.9%	6.7%	8.1%	8.7%	9.3%	9.8%	9.8%	13.4%	
Pedal cyclist	Total	568	1260	1451	1571	1374	1359	1486	1453	
	No-confirmed substances	191	326	296	288	253	251	333	259	<0.0001
		62.2%	59.3%	57.6%	54.5%	53.8%	52.0%	59.0%	53.5%	
	PCS	11	61	66	74	63	82	69	99	
		3.6%	11.1%	12.8%	14.0%	13.4%	17.0%	12.2%	20.5%	
Machinery	Total	307	550	514	528	470	483	564	484	
	No-confirmed substances	99	145	136	165	173	171	190	175	<0.0001
		61.5%	49.3%	48.7%	52.5%	46.6%	46.3%	51.8%	47.2%	
	PCS	3	16	36	29	34	56	34	50	
		1.9%	5.4%	12.9%	9.2%	9.2%	15.2%	9.3%	13.5%	
Natural	Total	161	294	279	314	371	369	367	371	
	No-confirmed substances	100	139	141	172	137	139	162	129	<0.0001
		49.3%	44.3%	45.8%	51.2%	46.3%	49.5%	46.7%	43.7%	
	PCS	12	29	28	22	27	39	37	50	
		5.9%	9.2%	9.1%	6.5%	9.1%	13.9%	10.7%	16.9%	
Pedestrian	Total	203	314	308	336	296	281	347	295	
	No-confirmed substances	26	32	58	71	60	81	69	76	0.27
		31.3%	27.8%	38.7%	39.9%	34.1%	42.6%	33.0%	34.7%	
	PCS	10	16	17	23	19	29	42	31	
		12.0%	13.9%	11.3%	12.9%	10.8%	15.3%	20.1%	14.2%	
Suffocation	Total	83	115	150	178	176	190	209	219	
	No-confirmed substances	11	32	15	22	17	20	28	24	0.002
		61.1%	45.7%	28.3%	36.7%	28.8%	32.8%	36.4%	34.3%	
	PCS	0	8	12	9	14	12	21	21	
Poison		0.0%	11.4%	22.6%	15.0%	23.7%	19.7%	27.3%	30.0%	

(continued on next page)

Table 2a (*continued*)

Year		2007	2008	2009	2010	2011	2012	2013	2014	*p*-value
	Total	18	70	53	60	59	61	77	70	
	No-confirmed substances	10	29	22	36	20	18	30	21	0.04
		35.7%	46.0%	50.0%	60.0%	45.5%	36.7%	50.8%	53.8%	
	PCS	0	7	2	3	5	9	9	6	
		0.0%	11.1%	4.5%	5.0%	11.4%	18.4%	15.3%	15.4%	
Drown	Total	28	63	44	60	44	49	59	39	

Table 2b
Number and proportion of visits for prescription controlled substances and no-confirmed substances by injury intent, National Trauma Data Bank, 2007–2014.

Year		2007	2008	2009	2010	2011	2012	2013	2014	p-value
Unintentional	No-confirmed substances	1739	6429	8020	8718	8115	9921	10,089	11,742	<0.0001
		48.6%	51.6%	50.2%	49.5%	48.1%	46.2%	50.3%	49.7%	
	PCS	19,442	35,687	36,249	37,465	34,929	34,132	39,730	38,687	
		4.3%	9.3%	11.1%	11.5%	11.2%	13.4%	12.8%	15.1%	
	Total	40,026	69,120	72,171	75,671	72,606	73,821	78,934	77,881	
Assault	No-confirmed substances	3114	5931	6129	5794	4920	5078	5540	4959	<0.0001
		33.4%	37.9%	36.4%	35.6%	32.1%	32.1%	34.8%	32.8%	
	PCS	259	921	1219	1150	897	1153	1167	1405	
		2.8%	5.9%	7.2%	7.1%	5.9%	7.3%	7.3%	9.3%	
	Total	9312	15,655	16,833	16,294	15,330	15,842	15,934	15,124	
Self-harm	No-confirmed substances	520	944	1074	1134	1078	1212	1259	1276	<0.0001
		38.1%	40.1%	39.5%	39.9%	37.4%	39.3%	40.6%	40.7%	
	PCS	82	280	330	387	424	521	523	556	
		6.0%	11.9%	12.1%	13.6%	14.7%	16.9%	16.9%	17.8%	
	Total	1364	2353	2720	2841	2880	3081	3099	3132	
Undetermined	No-confirmed substances	104	198	172	215	187	179	197	192	<0.0001
		33.4%	41.3%	34.4%	36.4%	33.6%	31.7%	34.2%	32.1%	
	PCS	17	35	35	47	52	70	61	63	
		5.5%	7.3%	7.0%	8.0%	9.4%	12.4%	10.6%	10.5%	
	Total	311	480	500	590	556	564	576	599	

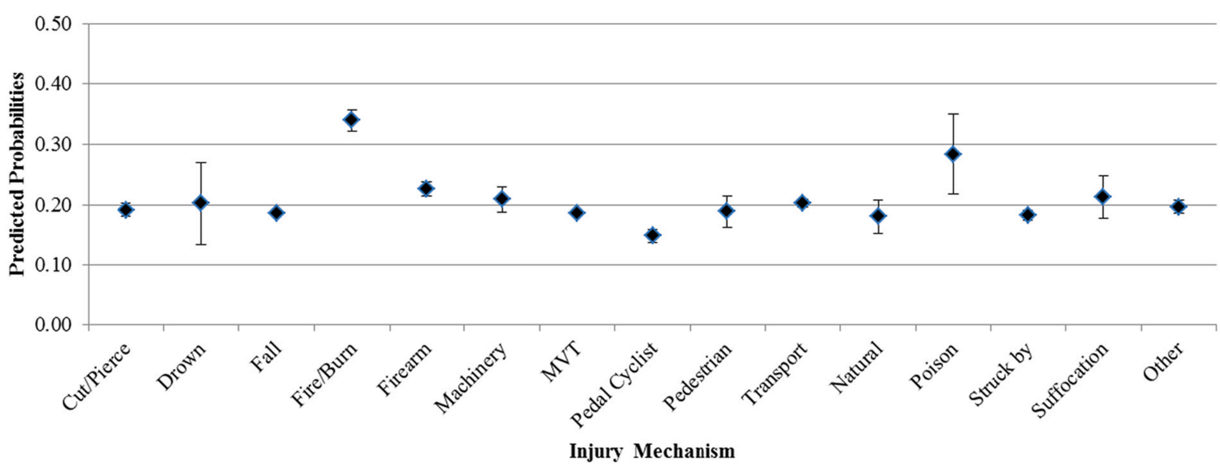

Fig. 2. Predicted probabilities for prescription controlled substance related traumatic injuries by injury mechanism, National Trauma Data Bank, 2007–2014. NOTE: The predicted probabilities and 95% confidence intervals presented in the figure were produced from the results of the fully-adjusted logistic regression models. They provide estimates of the probability of an injury event involving prescription controlled substances for a given injury mechanism.

associated with PCS, as well as trends and changes over time, from the NTDB. Results found that certain injury mechanisms, notably fire/burn, firearm, machinery, and other transport were more likely to be associated with PCS, while pedal cyclist injuries were the only injury mechanism less likely to be associated with PCS. Additionally, patients 26–65 years relative to patients 16–25 years and the injury intent of self-harm relative to unintentional injuries were more likely to have PCS detected.

Studies that examined patient and injury characteristics associated with controlled substance-related trauma report varying findings, likely as a result of differing definitions of substance use. Previous research found the injury mechanisms of fall were more likely and firearm less likely to be associated with controlled substances, while another study found no differences in injury mechanisms for those who tested positive for controlled substances (Pandya et al., 2015; Cannon et al., 2014; Soderstrom et al., 2001). Results from the present study specifically examining PCS found a wide range of injury mechanisms associated with PCS demonstrating the broad risk of injury associated with PCS use. Unlike previous research, though, patients >65 years were less likely to have PCS detected relative to the youngest age group. Due to the cross-sectional nature of the present study inferences cannot be drawn on the direction of the effect between PCS and traumatic injuries. The prescribing of controlled substances, particularly opioids, however, has grown dramatically, remaining at historically elevated levels despite recent improvements in prescribing practices (Centers for Disease

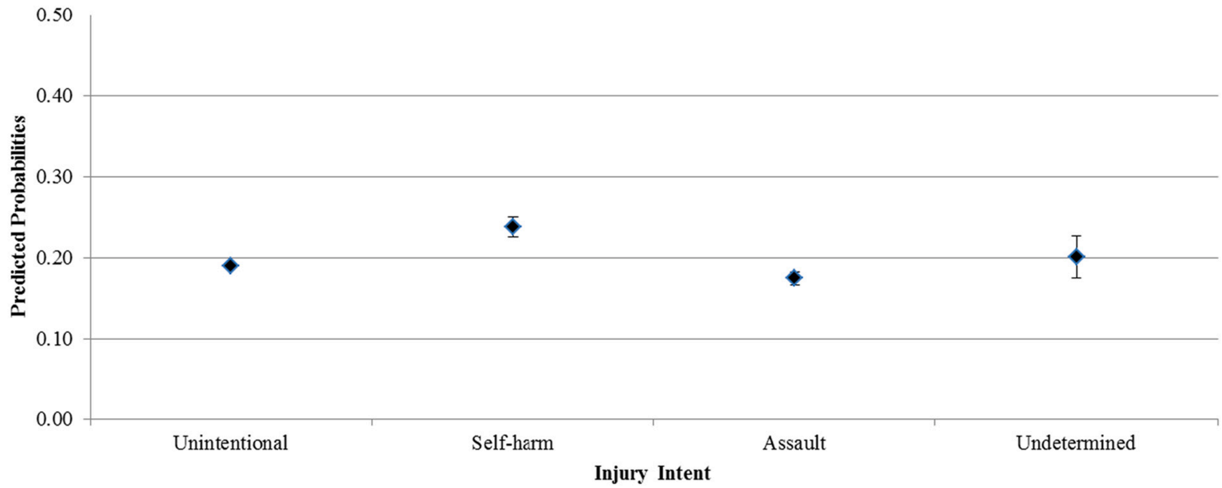

Fig. 3. Predicted probabilities for prescription controlled substance related traumatic injuries by injury intet, National Trauma Data Bank, 2007–2014.
NOTE: The predicted probabilities and 95% confidence intervals presented in the figure were produced from the results of the fully-adjusted logistic regression models. They provide estimates of the probability of an injury event involving prescription controlled substances for a given injury intent.

Control and Prevention, 2019). This calls for future research with a prospective cohort of patients to examine the effect of PCS on traumatic injuries.

Self-harm injury intent was more likely to have PCS detected on toxicology. Determining injury intent is rife with challenges, and misclassification of suicide and self-harm events is evident (Stone et al., 2017; Rockett et al., 2014; Kapusta et al., 2011). This means the results of this study are likely an underestimate of the true association between self-harm injury intent and PCS. Injuries as a result of self-harm often occur among individuals with underlying mental health conditions that may or may not be diagnosed. Apart from the treatment of the acute event, hospital treatment offers an opportunity for mental health screenings regardless of the initial suspected injury intent. For trauma events as a result of self-harm or undetermined intent, further support and linkage to mental health care are required during hospital treatment as well as upon release. The trauma event serves as an opportunity to connect individuals with care and support to treat mental health conditions.

The proportion of PCS-related visits for all injury mechanisms increased significantly from 2007 to 2014. These results highlight the significant and growing impact PCS play in trauma cases. Because PCS in the NTDB are drugs prescribed to patients, these trends likely identify related harms from the first phase of the opioid epidemic that was characterized by prescription opioid overdoses. This remains relevant because prescription opioid overdoses still occur, prescribing practices remain a concern, and prescription opioid use has been associated with increased risk for traumatic injury and mortality (Gomes et al., 2013; von Oelreich et al., 2020). PCS have meaningful roles in the treatment and management of health conditions, but, as the results from the present study showcase, they also increase risks for traumatic injury across a range of injury, demographic, and patient factors. For example, patients 65 and under were more likely to experience PCS-related trauma, while those over 65 years were less likely. Male patients were also less likely to have PCS detected, and the same was found for non-white patients who were less likely than white patients to have PCS detected. The reasons for these patterns remain unclear, and future research should examine if these results indicate a shifting population that uses PCS and if use of PCS leads to higher trauma risk for certain populations. Additionally, future research is needed to build upon this work to understand the associations with traumatic injury in light of recent trends in the opioid epidemic. These findings can be used now, though, to inform providers, pharmacists, and health care professionals on the importance of appropriate prescribing and an understanding of risk factors to reduce the likelihood of PCS-related traumatic injury.

There are limitations to this study that should be considered. First, this study was limited to only patients with toxicology testing; many patients do not have toxicology testing performed. Among these patients, there is also a lack of detail and specificity surrounding the PCS that is identified, including the type of PCS and an inability to identify multiple PCS. The toxicology data simply provide information on the presence or absence of substances. Furthermore, the specific level or test result for a substance cannot be determined from this data source. This contextual information is important for determining the role and effects a substance may have in a trauma case. Finally, although the NTDB provides a standard format and database, the data quality reflects participation and adherence to reporting guidelines by contributing hospitals. Furthermore, the toxicology testing standards and reporting protocol likely vary between participating facilities. Nevertheless, the strength of this study lies in the use of the sizable, nationally representative study population from the NTDB.

5. Conclusions

The results presented here highlight predictors of PCS-related trauma, including patient characteristics, injury mechanism, and injury intent, as well as how these have changed over the study period. Overall, PCS-related trauma increased significantly over time, especially among women and younger patients. PCS increase the risk for traumatic injuries and the results presented here support and add to previous findings by examining the role of PCS. Future research should investigate why patients do not have toxicology testing completed, and differentiate specific drugs, as well as levels of substances among cohorts of patients with PCS to more fully understand the role of PCS in traumatic injuries. Due to their ubiquity in traumatic injury events, these findings can be used to inform providers, pharmacists, and health care professionals to result in informed prescribing and an understanding of risk factors to reduce the likelihood of PCS-related traumatic injury.

Source of funding

Funding for this research was provided by the U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health (award number T42OH008434) to the Midwest Center for Occupational Health and Safety at the University of Minnesota School of Public Health as part of the Education and Research Centers funding.

CRediT authorship contribution statement

Nate Wright: Methodology, Software, Validation, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Marizen R. Ramirez:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Funding acquisition. **Bronwyn Southwell:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Mark Hemmila:** Conceptualization, Methodology, Writing – original draft. **Lena Napolitano:** Conceptualization, Methodology, Writing – original draft. **Christopher J. Tignanelli:** Conceptualization, Methodology, Software, Validation, Formal analysis, Resources, Data curation, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Mark Hemmila receives salary support from Blue Cross Blue Shield of Michigan and Blue Care Network (a nonprofit mutual company) through their support of the Michigan Trauma Quality Improvement Program. For the remaining authors, no conflicts were declared.

Data availability

The authors do not have permission to share data.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2022.107275.

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