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Adding to the story, did penetrating trauma really increase? changes in trauma patterns during the COVID-19 pandemic: A multi-institutional, multi-region investigation☆,☆☆

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A R T I C L E I N F O

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A B S T R A C T

Background: Results from single-region studies suggest that stay at home orders (SAHOs) had unforeseen consequences on the volume and patterns of traumatic injury during the initial months of the Coronavirus disease 2019 (COVID-19). The aim of this study was to describe, using a multi-regional approach, the effects of COVID-19 SAHOs on trauma volume and patterns of traumatic injury in the US.
Methods: A retrospective cohort study was performed at four verified Level I trauma centers spanning three geographical regions across the United States (US). The study period spanned from April 1, 2020 – July 31, 2020 including a month-matched 2019 cohort. Patients were categorized into pre-COVID-19 (PCOV19) and first COVID-19 surge (FCOV19S) cohorts. Patient demographic, injury, and outcome data were collected via Trauma Registry queries. Univariate and multivariate analyses were performed.
Results: A total 5,616 patients presented to participating study centers during the PCOV19 (2,916) and FCOV19S (2,700) study periods. Blunt injury volume decreased ($p = 0.006$) due to a significant reduction in the number of motor vehicle collisions (MVCs) ($p = 0.003$). Penetrating trauma experienced a significant increase, 8% (246/2916) in 2019 to 11% (285/2,700) in 2020 ($p = 0.007$), which was associated with study site ($p = 0.002$), not SAHOs. Finally, study site was significantly associated with changes in nearly all injury mechanisms, whereas SAHOs accounted for observed decreases in calculated weekly averages of blunt injuries ($p < 0.02$) and MVCs ($p = 0.003$).
Conclusion: Results of this study suggest that COVID-19 and initial SAHOs had variable consequences on patterns of traumatic injury, and that region-specific shifts in traumatic injury ensued during initial SAHOs. These results suggest that other factors, potentially socioeconomic or cultural, confound trauma volumes and types arising from SAHOs. Future analyses must consider how regional changes may be obscured with pooled cohorts, and focus on characterizing community-level changes to aid municipal preparation for future similar events.

Introduction

The World Health Organization (WHO) labeled the Coronavirus disease 2019 (COVID-19) a world pandemic on March 11, 2020 [1]. In response to the exponential global spread of COVID-19, local, state, national, and international travel restrictions and lockdowns/stay at home orders (SAHOs) were implemented with the

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aim to “flatten the curve” [2–4]. The first stay at home advisory/mandate in the US was implemented March 19, 2020 in California, with the majority of states quickly following suit [2]. US travel rates significantly decreased immediately following implementation of SAHOs [5]. During this same time period, multiple cities reported significant increases in violent crime and gun-related violence, suggesting that social distancing measures did not decrease gun violence [6–13]. Media outlets reported on increased rates in violent crime using anecdotal evidence to support their claims, propagating the narrative suggesting a foreseeable rise in violent crime. This prediction was substantiated following the release of a year-end report by the Council on Criminal Justice (CCJ) [14]. This report described a sharp rise in homicide rate, aggravated assaults, and gun assaults during the pandemic juxtaposed by noticeable drops in robbery, residential burglary, and drug-related offenses. However, the question remained whether these changes in violent crime and travel patterns would impact trauma resource utilization, and if yes, how? Many single institution or single-region investigations completed by the academic trauma community reported a significant decrease in total trauma volume with a minor yet important shift towards higher proportions of penetrating injuries during the first part of the COVID-19 pandemic [15–20].

Currently, no study has investigated the influence of the COVID-19 pandemic on the volume and patterns of traumatic injury across US regions. Therefore, we aimed to: 1) confirm or reject observed trends in patterns of traumatic injury described by recent single region studies on a multi-regional level; 2) determine if changes in trauma patterns that occurred during the COVID-19 pandemic were uniform across multiple regions; and 3) characterize the association between study site, study period, and changes in trauma patterns during the COVID-19 pandemic. We hypothesized that aggregate multi-regional trauma data would confirm previous results regarding changes in patterns of traumatic injury during the initial months of COVID-19. We also postulated that region-specific variability in trauma patterns exist and that SAHOs may not independently explain these observed changes.

Materials methods

Ethical oversight

Ethical oversight for this study was performed by the Institutional Review Boards (IRBs) at participating institutions. Proof of IRB approval was required for study participation. Individually negotiated data use agreements were executed between participating institutions and the lead study institution. The present study complied with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines [21].

Study population and variables

Data were collected using institutional trauma registries (TRs) in a retrospective fashion. Institutional level data were captured using the Research Electronic Data Capture (REDCap) database. All adult (≥18 years old) patients presenting to one of four Level I trauma centers located in Massachusetts, Pennsylvania, Ohio, or Arizona between April 1, 2019 through July 31, 2019 (PCOV19) and April 1, 2020 through July 31, 2020 (FCOV19S) were included for analysis. Using the Johns Hopkins online COVID-19 Resource Hub, start and release dates of SAHOs/mandates were recorded for the states in which study institutions reside (**Supplemental Table 1**) [22]. Patients were dichotomized into the PCOV19 and FCOV19S patient groups.

The database generated for this study captured 11 variables for each patient. Institution of patient presentation was recorded. Collected demographic variables included age, sex, race, and ethnicity. Injury characteristics such as injury type (blunt, penetrating, other), mechanism of injury, and Injury Severity Score (ISS) were obtained. Injury mechanisms included: motor vehicle collisions (MVC), motorcycle crashes (MCC), falls, gunshot wounds (GSWs), stab wounds, and other. Suicide or domestic violence (DV) related trauma injuries were obtained from TR data (identified via International Classification of Disease 10 external causes of injury codes). Finally, hospital mortality was recorded.

Statistical analysis

Descriptive statistics were performed to summarize patient demographics, injury characteristics, and mortality rate. Median and interquartile ranges (IQRs) were recorded for continuous data, while categorical data were summarized using actual count (n) and percentages (%). Categorical variables were compared using Pearson’s Chi-squared test while continuous variables were compared using a Wilcoxon rank-sum test. Analysis of variance (ANOVA) and multivariate linear regression analyses were performed to characterize the association between study site (geographic region) and study period (SAHOs) on observed changes in trauma patterns. Specifically, weekly trauma volumes were generated for each study site, study period, and injury type/mechanism, and were then compared across all factors. Statistical analyses were performed using StataCorp 2017 (Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC) and Python 3.7 using the Pandas, Statsmodels, Matplotlib, and Seaborn packages. Figures were generated using Python 3.7 using the Pandas, Matplotlib, and seaborn packages, and Prism 9 software (GraphPad Software, La Jolla California USA).

Results

Aggregate population and patient characteristics

A total of 5616 patients presented to participating study centers during the PCOV19 (2916) and FCOV19S (2700) study periods. The median age for the PCOV19 cohort was 57 (inter-quartile range, IQR [35,75]) and 56 (IQR [34,74]) for the FCOV19S cohort ($p = 0.046$). The racial composition of presenting trauma patients was statistically different between the PCOV19 and FCOV19S cohorts ($p<0.001$). The frequency of female trauma patients decreased comparing the PCOV19 to the FCOV19S cohorts (42% vs. 36%, respectively; $p<0.001$). There was no change in the overall acuity of traumatic injury comparing the PCOV19 to FCOV19S patient populations, with a median ISS of 9 (IQR, [4,14]) and 9 (IQR, [4,14]) respectively ($p = 0.10$). These descriptive statistics can be found in Table 1.

Overall traumatic injury trends

The total number of traumatic injuries decreased comparing the PCOV19 ($n = 2916$) and FCOV19S ($n = 2700$) (Table 1) cohorts. Fig. 1 shows the association between rising incidence of COVID-19, implementation of SAHOs, and decreased trauma incidence. Similarly, Fig. 2 depicts the decreased number of traumatic injuries during April and May of 2020 compared to 2019.

Incidence of blunt and penetrating traumatic injury

The number of injuries from blunt trauma decreased comparing the PCOV19 (2661/2916 or 91%) to the FCOV19S (2405/2700, 89%) cohorts ($p = 0.006$). Conversely, the number of penetrating traumas increased from 246/2916 (8%) to 285/2700 (11%) ($p = 0.007$) (Table 1). Specifically, the number of patients presenting with blunt

Table 1
Demographic characteristics and hospital outcomes for trauma patients presenting to one of four Level I trauma centers during April 1, 2019 through July 31, 2019 (Pre-COVID-19) and April 1, 2020 through July 31, 2020 (First COVID-19 Surge).

	PCOV19 (n = 2916)	FCOV19S (n = 2700)	p-value
Age, median (IQR)	57 (35, 75)	56 (34, 74)	0.046
Female, n (%)	1235 (42%)	972 (36%)	<0.001
Race, n (%)			<0.001
White	2284 (78%)	21,04 (78%)	0.72
African American	281 (9%)	308 (11%)	0.03
Asian	35 (1%)	31 (1%)	0.717
American Indian, Pacific Islander, or Native Alaskan	26 (1%)	29 (1%)	0.488
Other/Unknown	290 (10%)	228 (9%)	0.007
Ethnicity, n (%)			0.14
Hispanic	270 (9%)	266 (10%)	0.45
Non-Hispanic	2630 (90%)	2408 (89%)	0.215
Unknown	16 (1%)	26 (1%)	
Injury Type, n (%)			0.023
Blunt	2661 (91%)	2405 (89%)	0.006
Penetrating	246 (8%)	285 (11%)	0.007
Other	9 (0.3%)	10 (0.4%)	
Injury Severity Score, median (IQR)	9 (4, 14)	9 (4, 14)	0.10
Injury Mechanism, n (%)			
MVC	586 (20%)	459 (17%)	0.003
MCC	180 (6%)	170 (6%)	0.85
Fall	1411 (48%)	1302 (48%)	0.90
GSW	124 (4%)	153 (6%)	0.014
Stab	85 (3%)	103 (4%)	0.061
Other	468 (16%)	462 (17%)	0.28
Suicide, n (%)	45 (2%)	36 (1%)	0.51
Domestic Violence, n (%)	20 (1%)	27 (1%)	0.20
Mortality, n (%)	112 (4%)	113 (4%)	0.51

Abbreviations: interquartile range (IQR), motor vehicle collision (MVC), motorcycle collision (MCC), gunshot wound (GSW).

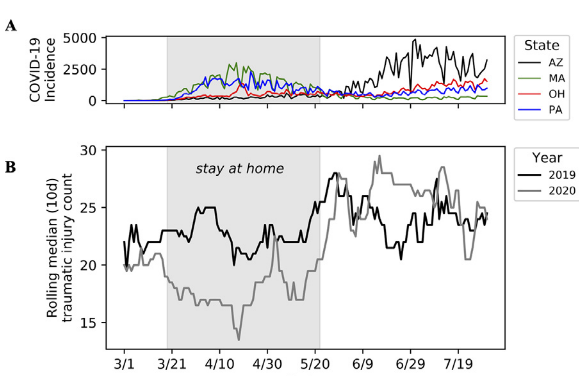

Fig. 1. Associated trends between daily COVID-19 incidence, implementation of SAHOs and daily incidence of traumatic injury. (A) The daily incidence of COVID-19 for Arizona, Massachusetts, Ohio, and Pennsylvania. (B) Trends in incidence of traumatic injury using 10 day rolling medians. gray highlighted region marks the date range of state-sponsored SAHOs. Data was obtained from the Johns Hopkins University COVID-19 GitHub webpage.

trauma in April and May of 2020 was less than the same two months of 2019, with blunt injury counts for June and July of 2020 returning to pre-lockdown levels (Fig. 2). With exception of April 2020, the number of patients presenting to trauma centers secondary to penetrating traumatic injuries was consistently higher in the FCOV19S cohort than PCOV19 cohort (Fig. 2).

Further investigations were performed to characterize changes in patterns of specific injury mechanisms to understand the driving force(s) behind previously described trends in total, blunt, and penetrating trauma. The frequency of specific injury types for both the PCOV19 and FCOV19S cohorts is shown in Fig. 2A. The cumulative number of monthly injury types and mechanisms (blunt, penetrating, MVCs, falls, GSWs, and stab wounds) between the PCOV19 and FCOV19S cohorts is depicted in Fig. 2B. A significant decrease in MVCs (p = 0.003) was observed (Table 1). The number of traumas resulting from fall-related injuries did not change during the FCOV19S study period. In contrast, a significant increase in the number of GSWs (p = 0.014) was observed between the FCOV19S and PCOV19 cohorts using combined data (Table 1); however, site specific trends in penetrating trauma mechanisms were observed.

Site specific changes in demographic and injury characteristics

Changes in patterns of traumatic injury during the COVID-19 study period were different across study site. Of the 5616 trauma patients, 25% (1417) presented to Massachusetts, 25% (1382) to Pennsylvania, 21% (1183) to the Arizona, and 29% (1635) to Ohio. Trauma volume decreased during the first four months of the pandemic in Massachusetts, Pennsylvania, and Arizona, while the Ohio cohort experienced a slightly increased trauma volume. Statistically significant differences in baseline demographics were identified comparing the FCOV19S to the PCOV19 cohorts at each study site. In the Massachusetts, Arizona, and Ohio cohorts, significant decreases in female trauma patients were observed. This decrease was not observed in the Pennsylvania cohort. The racial composition of trauma patients significantly changed among the Arizona Cohort, with an increased number of White, African American, and American Indian/Pacific Islander/Native Alaskan trauma patients. An increase in the number of Hispanic patients was observed in the FCOV19S cohort in Pennsylvania alone (PCOV19: 25/762, 3% vs FCOV19S: 44/620, 7%). An increased ISS (2019 5 [4,10] vs 2020 9 [4,11]; p = 0.008) during the FCOV19S study period was observed for the Pennsylvania cohort, whereas ISS did not significantly change for the remaining study sites comparing the two study periods. No significant changes in the overall volume of

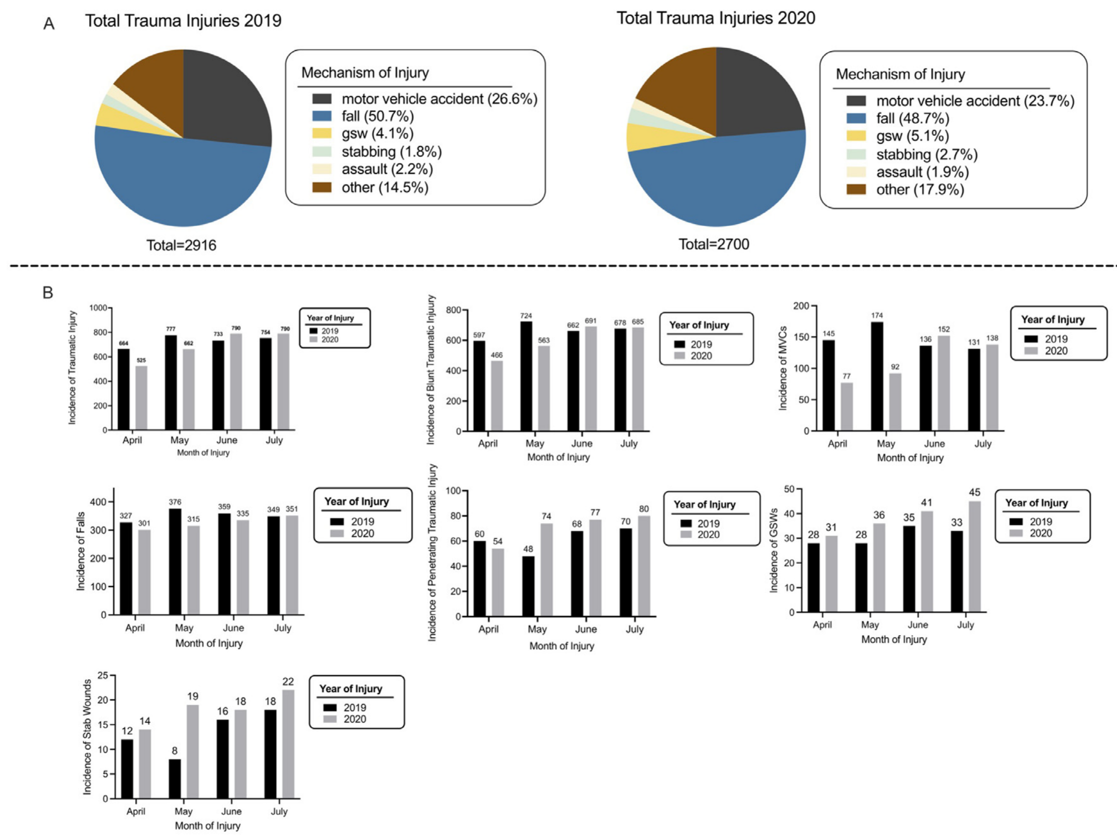

Fig. 2. Breakdown and comparison of pre-COVID-19 (2019) and COVID-19 first surge (2020) specific mechanisms of injuries. (A) Proportion of traumatic injury for pre-COVID-19 (2019) and COVID-19 first surge (2020) resulting from five different specific mechanisms of injury. (B) Statistical comparison of pre-COVID19 and COVID-19 first surge incidence of specific mechanisms of injury.

blunt or penetrating injuries were observed across all four study sites when comparing the PCOV19 and FCOV19S cohorts. There was no change in mortality rate across all study sites comparing PCOV19 and FCOV19S study periods. Please refer to Table 2 for details regarding specific numerical changes in demographic variables, trauma patterns, and mortality rate during the first four months of the COVID-19 pandemic by study site.

Changes in patterns of injury mechanisms across study sites were not uniform. Statistically significant changes in specific injury mechanisms were present in the Pennsylvania and Arizona cohorts. Comparing the PCOV19 to the FCOV19S cohort, Pennsylvania experienced a decrease in MVCs (160/762, 21% vs. 98/620, 16%) ($p = 0.014$) and increase in stab wounds (17/762, 2% vs. 31/620, 5%) ($p = 0.005$). The volume of all other injury mechanisms remained unchanged in Pennsylvania. In Arizona, MCCs significantly decreased (28/610, 5% vs. 12/573, 2%) ($p = 0.018$), and a significant increase in gun-related injuries was observed (38/610, 6% vs. 53/573, 9%) ($p = 0.05$). No significant changes in injury mechanisms were recorded for the Massachusetts or Ohio cohorts. Table 2 includes the above described results.

Factor(s) influencing changes in trauma patterns

Study period was used as a proxy for SAHOs. Study site was associated with the observed change in the weekly average number of total traumas comparing the PCOV19 to the FCOV19S cohorts ($p < 0.001$); however, study period (SAHOs) was not found to be independently associated with this observed decrease in weekly mean trauma volume (at the 0.05 level). In summary, SAHOs accounted for the observed decrease in the weekly mean number of blunt injuries ($p = 0.028$) and MVCs ($p = 0.003$) (Fig. 3). Comparatively, study site was found to account for observed changes in the mean number of weekly injuries across nearly all injury mechanisms (except stab wounds).

Incidence of suicide and domestic violence

No significant change in the number of attempted suicide-related traumatic injury (as accounted for by TRs) was recorded between PCOV19 and FCOV19S study periods ($p = 0.51$) (Table 1). Changes in trauma volume resulting from domestic violence were not significant comparing the PCOV19 to the FCOV19S study periods ($p = 0.2$). At the institutional level, similar results were described (Table 2). **Supplementary Figure 1A & 1B** portray monthly trends in the number of attempted suicides and domestic violence resulting in traumatic injury.

Discussion

In this novel multi-regional, multi-institutional study we described region specific trends in trauma patterns that, to our knowledge, have yet to be described. Following analysis of aggregate patient data from four study sites located across three US geographic regions, total trauma volume decreased in 2020 compared to 2019. When analyzed at the level of the study site, this finding was not observed in the Ohio cohort, which experienced increased trauma volume during the FCOV19S study period. Overall, injury types shifted towards decreased blunt and increased penetrating injuries. This was consistent with previously reported patterns of trauma during the COVID-19 pandemic suggest decreased total trauma volume with statistically significant decreases in blunt injury and concomitant marginal increases in penetrating trauma

Table 2
Site specific demographic characteristics and hospital outcomes for trauma patients comparing the PCOV19 to FCOV19S study periods.

	Boston			Pennsylvania			Arizona			Ohio		
	PCOV19 ($n = 735$)	FCOV19S ($n = 682$)	p-value	PCOV19 ($n = 762$)	FCOV19S ($n = 620$)	p-value	PCOV19 ($n = 610$)	FCOV19S ($n = 573$)	p-value	PCOV19 ($n = 810$)	FCOV19S ($n = 825$)	p-value
Age, median (IQR)	64 (41, 80)	62 (42, 76)	0.095	61 (41, 78)	59 (37, 77)	0.27	49 (30, 67)	48 (30, 69)	0.97	52 (32, 73)	52 (33, 71)	0.52
Female, n (%)	338 (46.0%)	253 (37.1%)	<0.001	341 (45%)	258 (42%)	0.24	249 (41%)	192 (34%)	0.009	307 (38%)	269 (33%)	0.024
Race, n (%)			0.4			0.092			<0.001			0.91
White	588 (80%)	523 (77%)		653 (86%)	516 (83%)		403 (66%)	425 (74%)		640 (79%)	640 (78%)	
African American	33 (5%)	46 (7%)		61 (8%)	50 (8%)		42 (7%)	54 (9%)		145 (18%)	158 (19%)	
Asian	21 (3%)	22 (3%)		3 (0.4%)	0		5 (0.8%)	4 (0.7%)		6 (0.7%)	5 (0.6%)	
American Indian, Pacific Islander, or Native Alaskan	1 (0.1%)	1 (0.1%)		0	0		20 (3%)	23 (4%)		5 (0.6%)	5 (0.6%)	
Other/Unknown	92 (13%)	90 (13%)		45 (6%)	54 (9%)		140 (23%)	67 (12%)		13 (2%)	17 (2%)	
Ethnicity, n (%)			0.08			0.002			0.6			0.31
Hispanic	72 (10%)	70 (10%)		25 (3%)	44 (7%)		168 (28%)	150 (26%)		5 (1%)	2 (0.2%)	
Not-Hispanic	650 (88%)	587 (86%)		734 (96%)	576 (93%)		442 (73%)	423 (74%)		804 (99%)	822 (100%)	
Unknown	13 (2%)	25 (4%)		3 (0.4%)	0		0	0		0	1 (0.1%)	
Injury Type, n (%)			0.71			0.091			0.087			0.34
Blunt	682 (93%)	627 (92%)		702 (92%)	550 (89%)		540 (88%)	488 (85%)		737 (91%)	740 (90%)	
Penetrating	52 (7%)	53 (8%)		52 (7%)	62 (10%)		70 (12%)	85 (15%)		72 (9%)	85 (10%)	
Other/Unknown	1 (0.1%)	2 (0.3%)		8 (1%)	8 (1%)		0	0		0	0	
Injury Severity Score, median (IQR)	9 (5, 14)	9 (4, 16)	0.29	5 (4, 10)	9 (4, 11)	0.008	6 (4, 16)	5 (4, 13)	0.35	9 (5, 14)	9 (5, 16)	0.98
Injury Mechanism, n (%)												
MVC	66 (9.0%)	54 (7.9%)	0.47	160 (21%)	98 (16%)	0.014	124 (20%)	97 (17%)	0.13	236 (29%)	210 (26%)	0.092
MCC	32 (4.4%)	37 (5.4%)	0.35	66 (9%)	54 (9%)	0.97	28 (5%)	12 (2%)	0.018	54 (7%)	67 (8%)	0.26
Fall	462 (62.9%)	414 (60.7%)	0.4	380 (50%)	330 (53%)	0.21	255 (42%)	246 (43%)	0.69	314 (39%)	312 (38%)	0.68
GSW	9 (1.2%)	12 (1.8%)	0.4	30 (4%)	28 (5%)	0.59	38 (6%)	53 (9%)	0.05	47 (6%)	60 (7%)	0.23
Stab wound	20 (2.7%)	23 (3.4%)	0.48	17 (2%)	31 (5%)	0.005	26 (4%)	24 (4%)	0.95	22 (3%)	25 (3%)	0.71
Other	123 (16.7%)	123 (18.0%)	0.52	109 (14%)	79 (13%)	0.4	139 (23%)	141 (25%)	0.46	97 (12%)	119 (14%)	0.15
Suicide, n (%)	9 (1.2%)	11 (1.6%)	0.54	9 (1%)	3 (0.5%)	0.16	11 (2%)	5 (1%)	0.17	16 (2%)	17 (2%)	0.91
Domestic Violence, n (%)	3 (0.4%)	4 (0.6%)	0.63	7 (0.9%)	6 (1%)	0.93	1 (0.2%)	5 (1%)	0.086	9 (1%)	12 (2%)	0.54
Mortality, n (%)	26 (3.5%)	38 (5.6%)	0.065	30 (4%)	14 (2%)	0.077	16 (3%)	20 (4%)	0.39	40 (5%)	41 (5%)	0.98

Abbreviations: interquartile range (IQR), motor vehicle collision (MVC), motorcycle collision (MCC), gunshot wound (GSW).

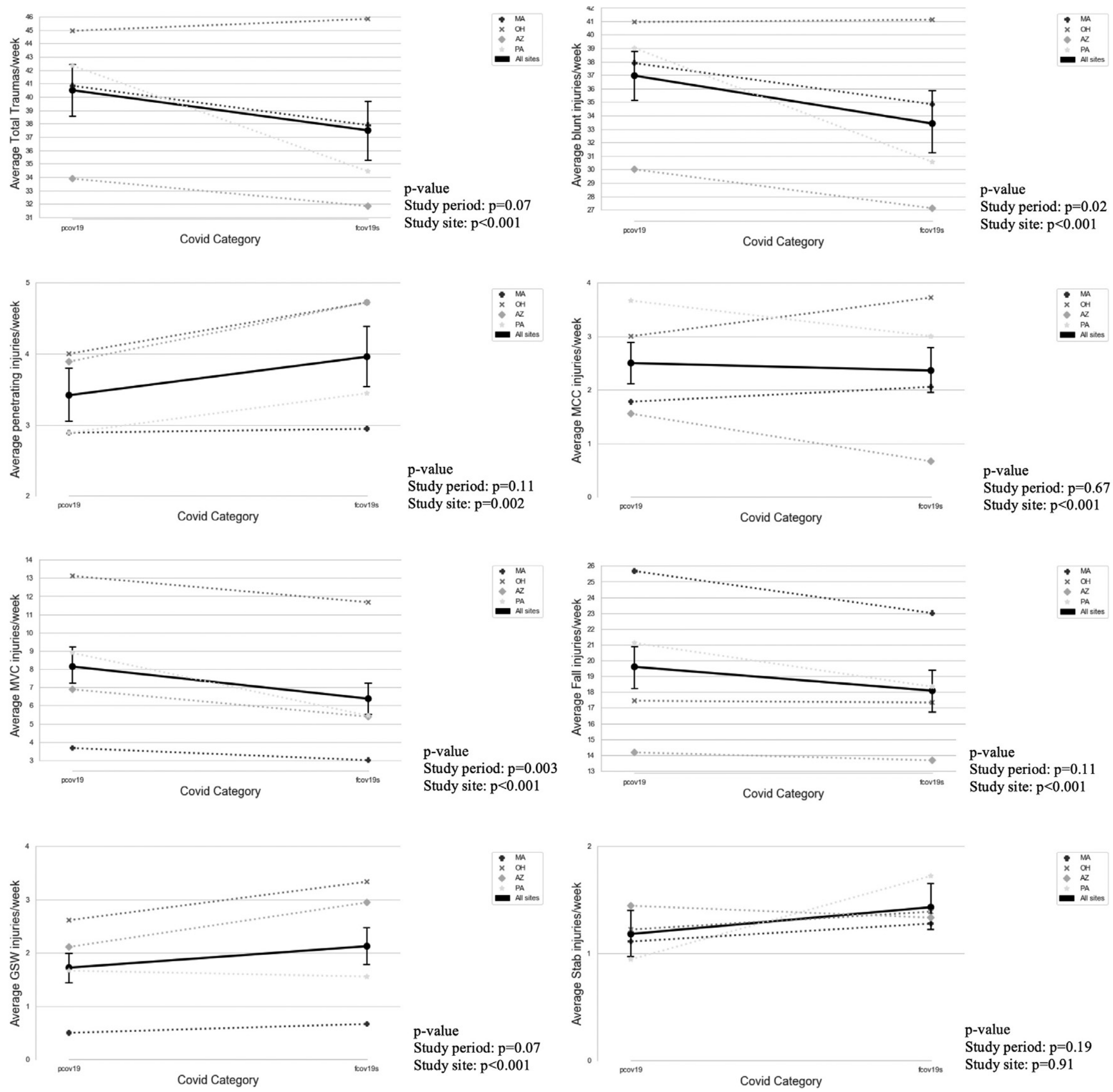

Fig. 3. Comparison of average weekly injuries comparing the PCOV19 to the FCOV19S study periods across all injury types and mechanisms. P-values indicate the association between study period or study site with observed changes in average weekly injuries.

during the COVID-19 pandemic [15–20]. Results from the present study refine and elaborate upon described changes in patterns of trauma during the pandemic by showing region specific responses in trauma patterns to implemented SAHOs.

Site-specific changes in trauma were observed. Specifically, study site was significantly associated with described changes for the majority of injury types and mechanisms while study period (2019 vs 2020 and proxy for SAHOs) was significantly associated with only decreased blunt injuries and MVC related trauma injury. The narrative that the pandemic resulted in increased penetrating violence may actually be more nuanced than previously reported and related to additional confounding local factors rather than a simple causal relationship to COVID-19 related social restrictions.

Notably, implementation of SAHOs were not centrally standardized, and varied at the state and local levels [23–26]. While some states implemented mandatory orders, others set forth advisories. Additionally, social isolation measures did not occur as a singular event, but rather in a step-wise fashion [4]. Such measures included a range of actions from closure of all non-COVID-19 essential business, to restrictions on group gatherings, transitioning to virtual learning and working, and local and international travel restrictions. Furthermore, the month in which first surge COVID-19 incidence peaks occurred were variable by state [4]. The cumulative effects of the above described inconsistent implementation of SAHOs may explain the lack of generalizability of single institution or single region studies to the national level and the need to describe changes in trauma patterns at the state and local level.

An immediate result of the stay at home advisories/mandates was a drastic decrease in automotive travel. Recent literature indicate that the proportion of trauma resulting from traffic related injury decreased during initial SAHOs. [17,18,20] Our data support previous trends showing a decrease in cumulative MVCs during the early stages of the pandemic compared to the PCOV19 study period. Furthermore, the present analysis indicated a direct association between SAHOs and decreased MVC-related trauma. By late April 2020, nearly all states had commenced stay at home advisories/mandates [2]. Estimates on total vehicle miles traveled by residents since the COVID-19 pandemic began, reported as the percent change from baseline, showed that household vehicle travel across the US decreased from 68–72% during the last weeks of March and first week of April 2020 compared to the first week in March 2020. [27,28] Put together, social isolation measures implemented throughout the US likely resulted in decreased volumes of MVC related trauma injuries.

This same association of SAHO could not be demonstrated with violent mechanisms of injury, including GSWs and stab wounds, following implementation of SAHOs. Past and present data support previous findings suggesting that SAHOs were not associated with decreased rates of gun violence, but in fact injury secondary to gun violence remained constant and in some locations increased. [6,29–34] This trend in gun violence may be attributable to drastic increases in gun sales, the turbulent social context in which the COVID-19 pandemic occurred, significant financial hardships due to lost jobs, and mental health consequences of social isolation measures implemented to curb the pandemic.

Past literature report mental health consequences of previous economic recessions and from the social isolation measures in response to the COVID-19 pandemic [35–41]. Recent studies report orthogonal results with respect to observed changes in suicide rate during SAHOs [42–44]. Our results did not indicate a significant change in suicide related traumatic injury. However, suicide mechanisms not catalogued by trauma registries, for instance overdoses, were not queried in this study and thus serve as a limitation to our data. Similarly, we did not observe a statistically significant increase in TR reports of DV. This result contradicts recent literature and a report released by the Council on Criminal Justice (CCJ) in February 2021 describing an 8% increase in DV following initiation of SAHOs [45–47]. Injuries resulting from DV often do not meet criteria requiring trauma activation, and as such TRs only capture a small percentage of individuals who experience DV.

In summary, present results suggest that SAHOs were associated with reduced motor vehicle related trauma but no relationship could be associated with other mechanisms of traumatic injury. Volume variation in other forms of trauma were related to site variability rather than a clear SAHO related trend. These results affirm the association between the reduction of MVC injuries with SAHOs and underscore the importance of geographic location in the incidence of other trauma patterns.

This study has a few limitations worthy of discussion. First, this study captures data for the first full four months of the COVID-19 pandemic and compares these data to that from the previous year. Therefore, this analysis and interpretation is limited to the first quarter of the pandemic. Future studies should compare 2020 trauma volume against multiple years of previous data to confirm results. Second, while this study captures data from four state or American College of Surgeons verified Level I trauma centers across four states and three geographic regions (Northeast, Midwest, Southwest), the overall generalizability of our findings across the entirety of the US may be limited. Area adherence to SAHOs was assumed, but it is possible that individual behaviors surrounding social distancing within our database may lack consistency. To date, no method exists to capture or quantify such data. Third, date ranges for initial SAHOs were nearly uniform across states where study sites are located (**Supplemental Table 1**). As such, we believe that our cohort captures regional responses to initial social restriction measures. Fourth, TRs do not include trauma related prehospital mortalities or patients dead on arrival to the hospital, thus our analysis may under-report the true trauma incidence. Lastly, TRs capture only a small fraction of suicide and DV related injuries, only those significant enough to warrant management by trained trauma surgeons. Therefore, it is likely that attempted suicide rates and rates of DV are higher than reported.

Conclusion

In summary, results from the present study indicate that region specific responses drove observed changes in trauma injuries during the first four months of the COVID-19 pandemic, except for a universal reduction in MVC related injury. Present results call into question the generalizability of single region findings to describe/the impact of social isolation measures on trauma patterns. Our results highlight the need for investigations into the multifactorial and likely complex socioeconomic factors effecting regional, state, and local trauma volumes to help educate trauma centers on how their local communities may respond to future similar events.

Authorship statement

Ava K. Mokhtari is the primary author for this original investigation. Along with Dr. Noelle Saillant, Ava was the key player for the conception of this study. She worked on study design, database design and development, and was also the lead study coordinator. She worked on data collection, performed a significant portion of the data analysis, review of the literature, was the key figure in manuscript preparation/table development and design/figure development, wrote the first manuscript draft, and worked on manuscript revisions. **Lydia R. Maurer** contributed to study conception, study design, site recruitment, data collection, data interpretation, manuscript writing, table and figure design, critical manuscript revisions, and helped with study supervision. **Michael Dezube** contributed to study design, data analysis and interpretation, table and figure design, manuscript writing, and critical manuscript revisions. **Kimberly Langeveld** contributed to study design, data collection, data interpretation, manuscript writing, and critical revisions. **Yee M. Wong** contributed to study design, data collection, data interpretation, and manuscript writing and critical revisions. **Claire Hardman** contributed to study design, played a significant role in data collection, aided in manuscript writing and critical revisions. **Shabnam Hafiz** contributed to study design, data collection, data interpretation, and manuscript writing and critical revisions. **Mark Sharrah** contributed to study design, played a significant role in data collection, aided in manuscript writing and critical revisions. **Hahn Soe-Lin** contributed to study design, data collection, data interpretation, and manuscript writing and critical revisions. **Kristina M. Chapple** contributed to study design, played a significant role in data collection, data interpretation, table and figure design, manuscript writing, and critical manuscript revisions. **Rafael Peralta** aided with study design, played a significant role in data collection, and helped with manuscript revisions. **Rishi Rattan** contributed to study design, data interpretation, manuscript writing and critical revisions. **Caroline Butler** contributed to study design, data interpretation, manuscript writing and critical revisions. **Jonathan J Parks** contributed to site recruitment and data collection, data interpretation, and aided in manuscript writing and critical manuscript revisions. **April E Mendoza** contributed to study design, data interpretation, and aided in manuscript writing and critical manuscript revisions. **George C. Velmahos** aided in data interpretation and manuscript writing and critical revisions. **Noelle N. Saillant** is the Principal Investigator for this study. Along with Dr. Ava K. Mokhtari, she helped guide study conception. She worked on study design and database design and development. She oversaw data collection and data analysis, was the key figure in manuscript preparation/table development and design/figure development, and performed a significant amount of work on manuscript revisions. Dr. Saillant provided continuous study supervision and support.

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Conflicts of Interest

None.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.injury.2022.02.034.

References

[1] Archived: WHO Timeline COVID-19. Published April 27, 2020. Accessed February 6, 2021. https://www.who.int/news/item/27-04-2020-who-timeline—covid-19.

[2] Moreland A, Herlihy C, Tynan M, Sunshine G, McCord RF, Hilton C, et al. Timing of state and territorial COVID-19 stay-at-home orders and changes in population movement–United States, March1-May31, 2020. MMWR Morb Mortal Wkly Rep 2020 2020;69:1198–203.

[3] Policy Response to Covid-19. International Monetary Fund. https://www.imf.org/en/Topics/imf-and-covid19/Policy-Responses-to-COVID-19.

[4] Dong E, Du H, Gardner L. An interactive web-based dashboard to track COVID-19 in real time. Lancet Inf Dis 2020;20(5):533–4.

[5] This Week In Transportation: Selected Transportation Measures Compiled by BTS During the COVID-19 Public Health Emergency. United States Department of Transportation. Published May 14, 2020. https://cms7.bts.dot.gov/covid-19/week-in-transportation.

[6] Sutherland M, McKenney M, Elkbuli A. Gun violence during COVID-19 pandemic: paradoxical trends in New York City, Chicago, Los Angeles and Baltimore. Am J Emerg Med 2021;39:225–6 10.1016/j.ajem.2020.05.006xf.

[7] Craig McCarthyMajor crime up 12% in NYC despite coronavirus outbreak. New York Press 2020 Published online April 2. https://nypost.com/2020/04/02/major-crimes-up-12-percent-in-nyc-despite-covid-19-outbreak/.

[8] City Wide Crime Statistics. New York City Police Department. Accessed February 6, 2021. https://www1.nyc.gov/site/nypd/stats/crime-statistics/citywide-crime-stats.page.

[9] Crime Map & Data Stats. Baltimore Police Department. Accessed February 6, 2021. https://www.baltimorepolice.org/crime-stats/crime-map-data-stats.

[10] Chicago Police Department Crime Statistics. Chicago Police Department 2000.

[11] NICS Firearm Checks:Month/Year. FBI. Accessed February 6, 2021. https://www.fbi.gov/file-repository/nics_firearm_checks_-_month_year.pdf/view.

[12] Beard JH, Jacoby SF, Maher Z, Dong B, Kaufman EJ, Goldberg AJ, et al. Changes in shooting incidence in Philadelphia, Pennsylvania, between march and november 2020. JAMA 2021;325(13):1327 10.1001/jama.2021.1534.

[13] Boman JH, Gallupe O. Has COVID-19 changed crime? Crime rates in the United States during the Pandemic. Am J Crim Just 2020;45(4):537–45 10.1007/s12103-020-09551-3.

[14] Rosenfeld R., Abt T., Lopez E.*Pandemic, social unrest, and crime in U.S. cities: 2020 year-end update*. Council on Criminal Justice. 2000.

[15] Forrester JD, Liou R, Knowlton LM, Jou RM, Spain DA. Impact of shelter-in-place order for COVID-19 on trauma activations: Santa Clara County, California, March 2020. Trauma Surg Acute Care Open 2020;5(1):e000505 10.1136/tsaco-2020-000505.

[16] Chodos M, Sarani B, Sparks A, Bruns B, Gupta S, Michetti CP, et al. Impact of COVID-19 pandemic on injury prevalence and pattern in the Washington, DC Metropolitan Region: a multicenter study by the American College of Surgeons Committee on Trauma, Washington, DC. Trauma Surg Acute Care Open 2021;6(1).

[17] Abdallah HO, Zhao C, Kaufman E, Hatchimonji J, Swendiman RA, Lewis Kaplan, et al. Increased firearm injury during the COVID-19 pandemic: a hidden urban burden. J. Am. Coll. Surg. 2021;232(2):159–68 e310.1016/j.jamcollsurg.2020.09.028.

[18] Leichtle SW, Rodas EB, Procter L, Bennett J, Schrader R, Aboutanos MB. The influence of a statewide "Stay-at-Home" order on trauma volume and patterns at a level 1 trauma center in the united states. Injury 2020;51(11):2437–41 10.1016/j.injury.2020.08.014.

[19] Qasim Z, Sjoholm LO, Volgraf J, Sailes S, Nance ML, Perks DH, et al. Trauma center activity and surge response during the early phase of the COVID-19 pandemic—The Philadelphia story. J Trauma Acute Care Surg 2020;89(4):821–8 10.1097/TA.0000000000002859.

[20] Ghafil C, Matsushima K, Ding L, Henry R, Inaba K. Trends in trauma admissions during the COVID-19 pandemic in Los Angeles County, California. JAMA Netw Open 2021;4(2):e211320 10.1001/jamanetworkopen.2021.1320.

[21] von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The strengthening the reporting of observational studies in epidemiology (STROBE) Statement: guidelines for reporting observational studies. Int J Surg 2014;12(12):1495–9 10.1016/j.ijsu.2014.07.013.

[22] Impact of Opening and Closing Decisions by State. Johns Hopkins University and Medicine Coronavirus Resource Center. Published May 28, 2021. Accessed May 28, 2021. https://coronavirus.jhu.edu/data/state-timeline.

[23] Stay Home Stay Healthy Stay Connected . Office of the Govenor Doug Ducey. Published March 30, 2020. https://azgovernor.gov/governor/news/2020/03/stay-home-stay-healthy-stay-connected.

[24] Governor Wolf and Health Secretary Issue 'Stay at Home' Orders to 7 Counties to Mitigate Spread of COVID-19. Govenor Tom Wolf. Published March 23, 2020. https://www.governor.pa.gov/newsroom/governor-wolf-and-health-secretary-issue-stay-at-home-orders-to-7-counties-to-mitigate-spread-of-covid-19/.

[25] Ohio Issues "Stay at Home" Order; New Restrictions Placed on Day Cares for Children. Mike DeWine Govenor of Ohio. 2000.

[26] Governor Charlie Baker Orders All Non-Essential Businesses To Cease In Person Operation, Directs the Department of Public Health to Issue Stay at Home Advisory For Two Weeks. Mass.gov. 2000.

[27] Get latest Vehicle Miles Traveled (VMT) data for U.S. counties, and monitor how it's changing. StreetLight Data. https://www.streetlightdata.com/vehicle-miles-traveled-vmt-monitor-by-county/#emergency-map-response. 2000.

[28] Dutzik T. America on pause: Vehicle travel during COVID-19 and what comes next. Frontier Group. Published April 20, 2020. https://frontiergroup.org/blogs/blog/fg/america-pause-vehicle-travel-during-covid-19-and-what-comes-next.

[29] Hatchimonji JS, Swendiman RA, Seamon MJ, Nance ML. Trauma does not quarantine: violence during the COVID-19 pandemic. Ann. Surg. 2020;272(2):e53–4 10.1097/SLA.0000000000003996.

[30] Kaufman E.Please, Stop Shooting. We Need the Beds. The New York Times. 2000

[31] Baltimore Mayor Begs Residents To Stop Shooting Each Other So Hospital Beds Can Be Used For Coronavirus Patients. WJZ 13 CBS Baltimore. 2000.

[32] Bates J. "We're Catching It Double." Amid Coronavirus Lockdowns, Gun Violence Continues to Plague Chicago. TIME. 2000.

[33] Abrams DS. COVID and crime: an early empirical look. SSRN Journal 2020 Published online10.2139/ssrn.3674032.

[34] Levine P, McKnight R. Three million more guns: the Spring 2020 spike in firearm sales. Brookings 2020 Published July 13Accessed February 6, 2021. https://www.brookings.edu/blog/up-front/2020/07/13/three-million-more-guns-the-spring-2020-spike-in-firearm-sales/.

[35] Holland K., Jones C., Vivolo-Kantor A., Idaikkadar N., Zwald M., Hoots B., et al. Trends in US emergency department visits for mental health, overdose, and violence outcomes before and during the COVID-19 pandemic. *Trends US Emerg Depart Visits for Mental Health, Overdose, and Violence Outcomes Before and During the COVID-19 Pandemic*. Published online February 3, 2021.

[36] Pollard MS, Tucker JS, Green HD. Changes in adult alcohol use and consequences during the COVID-19 Pandemic in the US. JAMA Netw Open 2020;3(9):e2022942 10.1001/jamanetworkopen.2020.22942.

[37] Galea S, Merchant RM, Lurie N. The mental health consequences of COVID-19 and physical distancing: the need for prevention and early intervention. JAMA Intern Med 2020;180(6):817 10.1001/jamainternmed.2020.1562.

[38] Xiang Y-T, Yang Y, Li W, Zhang L, Zhang Q, Cheung T, et al. Timely mental health care for the 2019 novel coronavirus outbreak is urgently needed. The Lancet Psychiatry 2020;7(3):228–9 10.1016/S2215-0366(20)30046-8.

[39] Reeves A, Stuckler D, McKee M, Gunnell D, Chang S-S, Basu S. Increase in state suicide rates in the USA during economic recession. The Lancet 2012;380(9856):1813–14 10.1016/S0140-6736(12)61910-2.

[40] Hamel L., Kearney A., Kirzinger A., Lopes L., Munana C., Brodie M. KFF Health Tracking Poll - July 2020. Kaiser Family Foundation.

[41] Panchal N., Kamal R., Cox C., Garfield R. The Implications of COVID-19 for Mental Health and Substance Use. Kaiser Family Foundation. Published February 10, 2021. https://www.kff.org/coronavirus-covid-19/issue-brief/the-implications-of-covid-19-for-mental-health-and-substance-use/

[42] Faust J.S., Shah S.B., Du C., Li S.-X., Lin Z., Krumholz H.M. *Suicide deaths during the stay-at-home advisory in massachusetts*. Epidemiology; 2020. doi:10.1101/2020.10.20.20215343.

[43] Sher L. The impact of the COVID-19 pandemic on suicide rates. QJM 2020;113(10):707–12 10.1093/qjmed/hcaa202.

[44] John A., Schmidt L. Full review data for: "The impact of the COVID-19 pandemic on self-harm and suicidal behaviour: update of living systematic review." Published online 2020. doi:10.7910/DVN/7WZXZK

[45] Fielding S. In quarantine with an abuser: surge in domestic violence reports linked to coronavirus. The Guardian 2020 Published April 3. https://www.theguardian.com/us-news/2020/apr/03/coronavirus-quarantine-abuse-domestic-violence.

[46] Evans ML, Lindauer M, Farrell ME. A Pandemic within a pandemic — Intimate partner violence during Covid-19. N Engl J Med 2020;383(24):2302–4 10.1056/NEJMp2024046.

[47] Piquero A., Jennings W., Jemison E., Kaukinen C., Knaul F. *Impact report: COVID-19 and domestic violence trends: evidence from a systematic review and meta-analysis*. Council on Criminal Justice; 2020.