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Evaluation of motor vehicle crash rates during and after the COVID-19-associated stay-at-home order in Connecticut

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ABSTRACT

Introduction: Recent research suggests that COVID-19 associated stay-at-home orders, or shelter-in-place orders, have impacted intra-and-interstate travel as well as motor vehicle crashes (crashes). We sought to further this research and to understand the impact of the stay-at-home order on crashes in the post order period in Connecticut.

Methods: We used a multiple-comparison group, interrupted time-series analysis design to compare crashes per 100 million vehicle miles traveled (VMT) per week in 2020 to the average of 2017–2019 from January 1-August 31. We stratified crash rate by severity and the number of vehicles involved. We modeled two interruption points reflecting the weeks Connecticut implemented (March 23rd, week 12) and rescinded (May 20th, week 20) its stay-at-home order.

Results: During the initial week of the stay-at-home order in Connecticut, there was an additional 28 single vehicle crashes compared to previous years (95% confidence interval (CI): [15.8, 36.8]). However, the increase at the order onset was not seen throughout the duration. Rescinding the stay-at-home order by and large did not result in an immediate increase in crash rates. Crash rates steadily returned to previous year averages during the post-stay-at-home period. Fatal crash rates were unaffected by the stay-at-home order and remained similar to previous year rates throughout the study duration.

Discussion: The initial onset of the stay-at-home order in Connecticut was associated with a sharp increase in the single vehicle crash rate but that increase was not sustained for the remainder of the stay-at-home order. Likely changes in driver characteristics during and after the order kept fatal crash rates similar to previous years.

1. Introduction

COVID-19, has impacted life on a scale unparalleled in the 21st century. In the U.S., around 615,000 COVID-19 deaths and around 26 million cases occurred in 2020 (Johns Hopkins University, 2021). In order to combat COVID-19, the majority of states implemented stay-at-home orders, or shelter-in-place orders, which restricted intra-and-interstate movement (Moreland et al., 2020; Sen et al., 2020). These stay-at-home orders, typically issued as gubernatorial executive orders, were implemented in March and April of 2020 and largely rescinded by May and June of 2020 (Moreland et al., 2020). Stay-at-home orders aimed to limit community-level exposure by reducing the amount of person-to-person transmission.

There have been several estimations of the impact of stay-at-home orders on crashes at the population-level, both within the U.S. and internationally. Inada, Ashraf, & Campbell (2020) examined whether changes in speed-related motor vehicle fatalities were associated with the stay-at-home order using police data from Japan (Inada et al., 2020). They found that the observed ratio of speed-related fatal crashes, compared to non-speed-related fatal crashes, was higher during the stay-
at-home order than the forecasted ratio using a decade of previous data. They note that speed-related fatal crashes likely increased during the stay-at-home order (Inada et al., 2020). Sutherland et al. (2020) examined crashes and crash-related injuries among four sites during the initial period of stay-at-home order. They found a reduction in the overall number of crashes and crash-related injuries in the initial stay-at-home period (Sutherland et al., 2020). However, the authors did not account for the documented reductions in crash exposure, commonly represented by vehicle miles traveled (VMT) (Shilling, 2020).

Doucette, Tucker, Augustine and colleagues (2020) examined crash rates per 100 Million (100 M) in Connecticut from January to April in 2017–2020 using a data repository of the state’s crash reports (Doucette et al., 2020). They used a single group interrupted time-series analysis to examine the changes to crash rates during the initial stay-at-home period within each year, stratified by crash severity and number of involved vehicles. They found that, while counts of crashes declined, the overall incidence rate of crashes from March 23rd to April 30th was not impacted by the stay-at-home order, despite a nearly 60% reduction in exposure. Further, they identified that rates of single vehicle crashes per 100 M VMT increased in the initial stay-at-home period in 2020, with the incidence rate of fatal single vehicle crashes increasing four-fold. Previous years, used as placebo tests, did not show similar results (Doucette et al., 2020).

Li, Neuroth, Valachovic and colleagues (2020) investigated the relationship between stay-at-home policies and traffic volume and injuries in Ohio comparing 2020 to 2019 using interrupted time-series. Traffic volume was obtained via state-level vehicle count stations positions on interstate, state, and US routes through Ohio and crash data was obtained from the Ohio Department of Public Safety’s Electronic Crash Submission database (Li et al., 2021). Researchers found crash injuries were 55% lower during the stay-at-home period in 2020 compared to the same period in 2019. They also identified mean daily counts of injuries in 2020 approached 2019 levels after the stay-at-home order was rescinded. Notably, crashes with severe or fatal injuries were not statistically different comparing 2020 to 2019 during and after the stay-at-home order.

The U.S. Department of Transportation’s National Highway Traffic Safety Administration issued several brief reports of early estimates of motor vehicle traffic fatalities and fatal rates in 2020 (National Center for Statistics and Analysis, 2021; Office of Behavioral Safety Research, 2021; Officer of Behavioral Safety Research, 2021; Wagner et al., 2020). These reports, which cover quarters 2, 3, & 4, of 2020, found increases in the estimates of both the number of fatal crashes and the fatal crash rate across American roadways. Fatal counts increased 9% related to single-vehicle crashes, 11% in speeding-related crashes, and 9% in police-reported alcohol involvement crashes (National Center for Statistics and Analysis, 2021). Wagner and colleagues (2020) found that in quarter 2 of 2020, drivers who remained on the road engaged in riskier behavior. These behaviors include speeding, failure to wear belt restraints, and intoxicated driving (Wagner et al., 2020).

As we move further from the stay-at-home orders of March-April 2020, it is important to advance our knowledge of what happened to crashes during and after the stay-at-home period in case future events necessitate similar social policy. As such, this study sought to understand the after-effects of the stay-at-home in Connecticut. We hypothesized that crash rates will increase in the post-stay-at-home period, approaching previous year averages.

2. Methods

We used an interrupted time-series design with multiple comparison groups to examine the whether the COVID-19 associated stay-at-home order affected crash rates in Connecticut. The current study built on previous research conducted by Doucette et al., (2020). Connecticut was used for this analysis because of its robust and publicly accessible crash data repository, which provides timely access to crash counts.

2.1. Data

Daily crash counts in Connecticut were collected from the Connecticut Crash Data Repository (CTCDDR) (Connecticut Crash Data Repository, 2021). Crashes were stratified by crash severity (any injury, fatal injury, no injury) and number of vehicles included in the crash (single vehicle vs. multiple vehicle). Estimates of daily vehicle miles traveled were collected from Streetlight’s Insight database (StreetLight Data, 2019). Daily measurements of average precipitation and maximum temperature were collected from the National Climatic Data Center’s Climate Data Online database (National Climatic Data Center, 2021). See Doucette et. al., (2020) for more information regarding data source and acquisition. Additionally, we included a monthly measure of unemployment to control for macroeconomic factors that may affect crash rates (He, 2016). Monthly unemployment data was collected from the Bureau of Labor Statistics’ Local Area Unemployment Statistics program (Bureau of Labor Statistics, 2021). All data was collected from January 1-August 31 for the years 2017, 2018, 2019, and 2020.

2.2. Analysis

We used an interrupted time-series analysis using multiple comparison groups to evaluate the initial and intermediate impact of COVID-19-related stay-at-home order on the daily crash rate per 100 M VMT per week (Bernal et al., 2017; Crosbie; Gottman; Hudson et al., 2019; Linden, 2015; Campbell and Stanley, 1966). We collapsed the daily crash rate to the week level to ease with interpretation. Connecticut’s stay-at-home order was in place from March 23rd to May 20th; thus, the pre-stay-at-home order period was weeks 1–11, the stay-at-home order period was weeks 12–20, and the post-stay-at-home order period was weeks 21–35. We used an average of the previous years (2017–2019) crash rate per 100 M VMT as the comparison group. We used the Stata program itsa to execute our analysis (Linden, 2015). This program uses ordinary least square regression-based models specifically designed for time-series data. For each outcome, we provided descriptive statistics related to the weekly counts, VMT, mean crash rate per 100 M VMT for the three study periods (pre, during, and post stay-at-home period).

To identify the treatment effect of the stay-at-home order, we specified a multiple-group interrupted time-series analysis with Newey-West standard errors wherein the treatment was the year 2020 and the control group was the average crash rate per 100 M VMT for 2017–2019 for each outcome. Newey-West standard errors, similar to the Huber & White sandwich standard errors, produce consistent standard errors when errors are autocorrelated and possibly heteroskedastic (Newey & West, 1987). We used the Comby-Huizinga test for autocorrelation, using the command actest, to ensure models account for correct autocorrelation structure (Baum and Schaffer, 2015; Comby and Huizinga, 1992). We assessed the level change, or the immediate change in crash rate, and slope change, or the change over time, associated with stay-at-home orders. Level and slope change were assessed at baseline to examine comparability of groups. We set two interruption points at week 12 and week 20 to examine the differences in 2020 crash rates to the average of 2017–2019 crash rates. Stata version 16.0 was used for all analyses (StataCorp., 2017).

3. Results

Table 1 displays mean weekly counts of crashes, VMT, and crash rates per 100 million for 2017–2019 and 2020 stratified by pre, during, and post stay-at-home order. Notably, the rates of overall crashes were lower in 2020 compared to the previous year’s averages throughout all three time periods. This was true for injurious and non-injurious crash rates as well as rates of crashes involving multiple cars. The rate of single car crashes was higher in 2020 during the stay-at-home period compared to the previous year’s average. The same was true for injurious and non-injurious single car crash rates. In the post-stay-at-home
period, single car crash rates were similar comparing 2020 to the previous three years. The fatal crash rate for 2020 during the stay-at-home order period was 23% higher than previous years (2020 = 0.42 per 100 million VMT; 2017–219 = 0.34 per 100 million VMT). Though, notably, weekly mean VMT in 2020 is nearly half of the previous three-year average.

Table 2 presents the pre-stay-at-home order crash rate intercept and slopes comparing 2020 to the average of the previous three years. Four outcomes - single vehicle crashes overall, injurious crashes overall, injurious single vehicle crashes, and non-injurious single vehicle crashes - had significantly different rate intercepts when comparing the treatment and control group in the pre-stay-at-home order period (Table 1). For all outcomes, there were no significant differences between treatment and control slopes in the pre-stay-at-home order period (Table 1) fulfilling the parallel trend assumption necessary for inference.

Most of the outcomes had some element of autocorrelation present. Models were fitted with an appropriate autoregressive lag based on their Cumby-Huizinga test for autocorrelation. The interrupted time-series analyses are presented in graphic form for crashes overall (Fig. 1a, 1b, 1c, 1d), single vehicle crashes (Fig. 2a, 2b, 2c, 2d) and multiple vehicle crashes (Fig. 3a, 3b, 3c, 3d) stratified by crash severity (a = overall, b = injurious, c = non-injurious, d = fatal). Table 3 presents the level and in slope change associated with the onset of the stay-at-home order and the rescinding of the stay-at-home order. At the onset of the stay-at-home order (March 23rd, or week 12), there were significant changes to crash rates in 2020. In the week the stay-at-home order was implemented, 2020 saw about 26 more single vehicle crashes per 100 M VMT (95% Confidence Interval (CI): (2.41, 8.58)) and about 20 more non-injurious single vehicle cashes (95% CI: (11.77, 28.55)) as well. No other outcomes saw significant changes to crash rates at the onset of the stay-at-home order, including fatal car crash rates. The increase in single car crashes overall, as well as

| Outcome                  | Pre-stay-at-home order Intercept Difference | Pre-stay-at-home order Slope difference |
|--------------------------|--------------------------------------------|----------------------------------------|
| Crashes, overall         | −49.14 [−99.37, 1.09]                      | 2.42 [−5.31, 10.17]                    |
| Single vehicle Crashes, overall | −16.50 [−26.72, 0.12]                     | 0.41 [−1.14, 1.97]                     |
| Multiple Vehicle Crashes, overall | −32.73 [−73.96, 8.50]                    | 2.03 [−4.41, 8.47]                     |
| Non-injurious Crashes, overall | −40.92 [−82.83, 0.98]                     | 2.07 [−4.32, 8.48]                     |
| Single vehicle, non-injurious Crashes | −13.40 [−22.58, 0.26]                   | 0.26 [−1.12, 1.66]                     |
| Multiple Vehicle, non- injurious Crashes | −27.51 [−61.39, 6.36]                  | 1.81 [−3.43, 7.06]                     |
| Injurious Crashes, overall | −8.17 [−16.34, −0.01]                     | 0.35 [−0.97, 1.67]                     |
| Single vehicle, Injurious Crashes | −3.07 [−8.48, −1.26]                     | 0.14 [−0.12, 0.418]                    |
| Multiple Vehicle, Injurious Crashes | −5.10 [−12.69, 2.49]                    | 0.20 [−1.0, 1.43]                      |
| Fatal Crashes, overall   | −0.03 [−0.180, −0.004]                    | −0.03 [−0.00, 0.02]                    |
| Single vehicle, Fatal Crashes | −0.02 [−0.14, 0.10]                      | −0.002 [−0.02, 0.02]                   |
| Multiple Vehicle, Fatal Crashes | −0.022 [−0.10, 0.05]                     | −0.002 [−0.01, 0.01]                   |

Note: Interrupted time-series analysis contains controls of weekly average precipitation and weekly average maximum temperature. Difference in level and slopes are the difference between treatment and control prior to intervention. Bold signifies p-value < 0.05.
injurious and non-injurious single car crashes, quickly dissipated, as the significantly steeper slope change during the stay-at-home period indicate. All crash types had significantly declining slopes in the stay-at-home period compared to the previous year average.

In the week that the stay-at-home order was rescinded (May 20th or week 20), Connecticut saw about seven additional injurious crashes per 100 M VMT (95% CI: [0.02, 14.73]) and 6 additional multi-vehicle, injurious crashes (95% CI: [0.37, 11.80]) compared to the average of 2017–2019. From May 20th and August 31st in Connecticut (or weeks 21–35) all non-fatal outcomes saw significant steeper linear slopes compared to 2017–2019. However, visible inspection of Figs. 1–3 as well as Table 1 shows that the mean weekly rate of crashes was lower in 2020 compared to 2017–2019 during the post-stay-at-home order. This indicates, as the order was rescinded, the rate of crashes started approaching previous year averages in a steady increase over time.

4. Discussion

Research presented here examined the crash rate per 100 M VMT per week before, during, and after the stay-at-home order in Connecticut, which was issued in 2020 during the COVID-19 pandemic. The year 2020 was compared to an average of the previous three years, revealing that the stay-at-home order’s onset was associated with a sharp increase in non-fatal, single vehicle crashes; however, crash rates did not remain
The single vehicle crash rate decreased significantly on a weekly basis throughout the roughly nine weeks of the stay-at-home order. The single vehicle crash rate was lower in 2020 during the post-stay-at-home period compared to that of previous years. As Table 1 and Figs. 1–3 suggest, the rate of crashes per 100 M VMT during the post-stay-at-home order period was significantly lower than during the stay-at-home period. This suggests that in any similar scenarios in the future, interventions can be targeted around the onset of shelter in place or stay-at-home orders to potentially reduce crash rates.

Table 3
Level and slope changes associated with the onset of the stay-at-home order and the rescinding of the stay-at-home order, comparing the treatment and control groups in Connecticut.

| Outcome                                      | Stay-at-Home Period Level Change | Slope Change | Post-Stay-at-Home Period Level Change | Slope Change |
|----------------------------------------------|----------------------------------|--------------|---------------------------------------|--------------|
| Crashes, overall                            | 14.3 ± 26.45, 55.06              | –16.92       | 20.65 ± 63.53                        | 7.27, 34.02  |
| Single vehicle Crashes, overall             | 25.86 ± 15.84, 36.88             | –6.28        | 7.04 ± 16.24                         | 2.95, 10.12  |
| Multiple Vehicle Crashes, overall           | –11.55 ± 42.44, 19.33            | –10.63       | 19.16 ± 46.91                        | 14.11, 23.91 |
| Non-injurious Crashes, overall              | 10.42 ± 22.94, 43.79             | –13.71       | 18.71 ± 48.87                        | 16.57, 27.66 |
| Single vehicle, non-injurious               | 20.16 ± 11.77, 28.55             | –5.12        | 4.64 ± 12.96                         | 4.74, 8.47   |
| Multiple Vehicle, non-injurious             | –9.74 ± 35.06, 15.57             | –8.58        | 5.64 ± 12.96                         | 4.54, 8.47   |
| Injurious Crashes, overall                  | 3.64 ± –5.47, 12.75              | –3.17        | 13.07 ± 11.96                        | 9.44, 19.22  |
| Single vehicle, Injurious                   | 5.50 ± 2.41, 8.58                | –1.12        | 7.38 ± 14.73                         | 4.03, 6.44   |
| Multiple Vehicle, Injurious                 | –1.85 ± –8.3, 4.58               | –2.04        | 6.08 ± 37.18                         | 3.00, 11.64  |
| Fatal Crashes, overall                      | 0.24 ± 0.19, 0.67                | –0.04        | 0.11 ± 0.5                           | 0.06, 0.07   |
| Single vehicle, Fatal Crashes               | –0.19 ± 0.17, 0.56               | –0.04        | 0.11 ± 0.5                           | 0.06, 0.14   |
| Multiple Vehicle, Fatal Crashes             | 0.04 ± 0.09, 0.18                | 0.001        | 0.005 ± 0.18                         | 0.003, 0.06  |

Note: Difference calculated by comparing the relative change in the post-intervention period to the pre-intervention period among the treatment group to that of the control group. Interrupted time-series analysis contains controls of weekly average precipitation, weekly average maximum temperature, and monthly unemployment. Bold signifies p-value < 0.05.

The rescinding of the stay-at-home order was largely not associated with immediate changes in crash rates though, the injurious crash rate and the multi-vehicle, injurious crash rate saw significant level changes during the week of the stay-at-home order’s removal. It is likely that the crash rate overall was not impacted because though the order was lifted, the COVID-19 pandemic was very much still active; Work from home policies were largely still in place as well as restrictions on dining and other consumer activities.

All non-fatal outcomes saw significant slope increases in weekly crash rates per 100 M VMT during the post-stay-at-home order period. This suggests that as the stay-at-home order was lifted, and thus intra- and interstate travel began returning to pre-stay-at-home order levels, there was a general increase in the rate of crashes per 100 M back to previous year averages. As Table 1 and Figs. 1–3 suggest, the rate of crashes was lower in 2020 during the post-stay-at-home period.
compared to the previous year averages. Thus, the significantly steeper slope in 2020 may be a return to prior year averages. This finding is similar to Li, et al., (2020) which found a return to normal crash rate in Ohio after the stay-at-home order (Li et al., 2021). We did not observe changes to the rate of fatal crashes. Policy makers may need to consider these impacts if limits are placed on intra- and interstate travel. It may be necessary to develop traffic easement procedures to ensure road traffic is as safe as possible in the period after the limits are lifted, as road traffic behaviors may change during the intervening time periods.

During and after the stay-at-home period, the weekly rate of fatal crashes did not change. This is true when inspecting the descriptive statistics from Table 1 and as well as when inspecting the time-series models in Table 3, which control for the weather as well as monthly unemployment. This finding is important as it suggests that despite reductions in vehicle miles traveled in Connecticut during 2020 (Doucette et al., 2020), the rate of fatal crashes may not have changed. It appears this may have been true during and after the stay-at-home period was implemented and lifted. This finding is consistent with previous research from the National Highway Traffic Safety Administration, which identified an increase in the rates of fatal car crashes (National Center for Statistics and Analysis, 2021).

Previous research suggests that changes in driving behavior associated with different road and social conditions in 2020 may have contributed to the increase in single vehicle crash rate seen in Connecticut, and the U.S., during the onset of the stay-at-home order (Doucette et al., 2020; Wagner et al., 2020). The current study adds that the initial week of the stay-at-home order itself may have presented a wholly unique circumstance as our findings suggest only an initial increase in single car crash rate occurred. Prior studies have found that single vehicle crashes and rates are associated with speeding and alcohol use, which may have increased during the early stages of the stay at home order (National Safety Council, 2020; Office of Behavioral Safety Research, 2021).

Fatal crash rates were unaffected by the COVID-19 pandemic as crash rates were similar in 2020 compared to the 2019–2017 average. This may be due in part because the population of drivers using the roads during and after the stay-at-home order may have changed. Telework-capable employees continued working from home throughout this period and the individuals with these positions are most likely non-elderly adults. As this population represents the lowest crash risk by age, the population still regularly driving may have exhibited increased crash risk. Changes in road conditions may also contributed to this issue. Traditionally, crash fatalities and driving decrease during recessions or times of high unemployment (He, 2016; Maheshri and Winston, 2016; Wegman et al., 2017). COVID-19 brought with it a large spike in unemployment and it is also possible that changes in crashes may have been impacted by unemployment levels. More research is needed to understand why fatal crash rates were unaffected in 2020 in Connecticut despite COVID-19 and its associated societal-level changes.

Further research is needed in the study of crashes around the period of stay-at-home orders, as these public policies greatly impacted travel. Specifically, research into the behavioral elements of crashes, such as crash rates related to intoxication or speeding, is greatly needed to complete the picture of what happened on roadways during the stay-at-home order periods and after. Analysis of crash rates stratified by age and sex are also needed. Additionally, other states with publicly available crash data should be considered for analysis.

4.1. Limitations

This study is not without limitations. A primary source of bias that may impact the relationship between stay-at-home orders and crash rates are other aspects of the COVID-19 pandemic. The pandemic’s associated media coverage, public fear, and anxiety, as well as economic uncertainty may have impacted who uses roads. We were unable to measure any changes to driver composition associated with COVID-19 independent of stay-at-home orders. Interrupted time-series analyses are susceptible to co-intervention bias. In this instance, there is limited potential for co-intervention bias to impact the results of our study, as our outcomes are within one state. To limit any given policy or societal change’s impact from previous years, we averaged the controls from 2017 to 2019. In 2020, a potential biasing event may have been the murder of George Floyd and the resulting protests for racial justice that were seen in Connecticut and throughout the world. However, looking at Figs. 1–3, there does not appear to be a spike in crash rate in 2020 around May 25th, the day of George Floyd’s death. During the post-stay-at-home order period, gubernatorial changes in the availability of retail establishments in Connecticut may have caused the crash rate to increase. However, an examination of non-fatal crashes in Figs. 1–3 shows a rather steady decline in the period, rather than steep changes associated with social policy and that steady decline is likely representative of a slow reopening process.

Results from the examination of baseline levels, as well as the presented figures, displayed that some crash types had significantly lower baseline levels of crash rate per 100 M VMT per week. However, all outcomes had similar slopes during the pre-stay-at-home period between the treatment and control groups related to crash rates per 100 M VMT per week. This suggests that the control group fulfilled the parallel line assumption necessary for a difference-in-difference calculation related to the changes associated with the implementation and removal of the stay-at-home order were likely valid.

This study’s generalizability is limited by its scope. While the use of multiple years of comparison builds our study’s interval validity, lack of data from outside Connecticut limits the study’s external validity. Still, there is reason to believe states that had similar reductions in intra- and interstate travel associated with stay-at-home orders may have had similar experiences with crash rates. More research into other states is needed to confirm this.

4.2. Conclusion

Understanding the impact of COVID-19 related stay-at-home orders is important in ensuring that future, similar social policies not have any negative health impacts. Findings here suggest that the time immediately following the issuing of a stay-at-home order may increase single vehicle crash rates and social policy should be designed to reduce that negative health outcome in future scenarios that warrant stay-at-home orders.

CRediT authorship contribution statement

Mitchell L. Doucette: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Supervision, Project administration. Andrew Tucker: Conceptualization, Methodology, Writing – review & editing, Project administration. Marisa E. Auguste: Conceptualization, Methodology, Writing – review & editing, Project administration. Johnathon D. Gates: Conceptualization, Writing – review & editing. David Shapiro: Conceptualization, Writing – review & editing. Johnathon P. Ehsani: Conceptualization, Writing – review & editing. Kevin T. Borrup: Conceptualization, Writing – review & editing, Supervision, Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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