Differences between occupational and non-occupational-related motor vehicle collisions in West Virginia: A cross-sectional and spatial analysis

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Background

Motor vehicle collisions comprise the majority of occupational-related fatalities in the United States and West Virginia has one of the highest occupational-related fatality rates in the nation. The purpose of this study was to compare work and non-work-related collisions, crash locations, and the characteristics of in-state and out-of-state drivers ≥18 years of age who were fatally injured in work-related collisions in West Virginia.

Methodology

Data were from the 2000–2017 Fatality Analysis Reporting System. Work and non-work-related crashes and characteristics in-state vs. out-of-state drivers were compared using binary and multivariable logistic regression analyses. Crash locations were compared via spatial analyses using kernel density estimations.

Results

Among the 5,835 individuals fatally injured in crashes, 209 were designated ‘at work’. The odds of being a work-related crash were 85% lower [Odds Ratio (OR) = 0.15; 95% confidence interval (CI): 0.04, 0.49] among those testing positive for alcohol, but 2.5 times greater (OR = 2.56; 95% CI: 1.16, 5.65) among those holding a commercial driver’s license. The odds of being an in-state driver were 75% lower (OR = 0.25; 95% CI: 0.12, 0.53) among workers testing drug positive (OR = 2.67; 95% CI: 1.10, 6.52). In-state drivers were also less likely to be driving a large truck or be involved in single vehicle collisions and less likely to experience crashes on weekends.
nights, or on highways. Spatial patterns of crash locations varied slightly between workers and non-workers.

**Conclusions**

Work-related crashes differed greatly from non-work-related crashes in West Virginia. Stark differences existed between in-state and out-of-state workers and their crashes. Various avenues for workplace safety interventions exist, including seatbelt initiatives and drug testing policies for non-commercial drivers, which could help mitigate West Virginia’s elevated, occupational-related, traffic fatality rate.

**Introduction**

According to the Bureau of Labor Statistics, there were 5,147 work-related fatalities in the United States (U.S.) in 2017 alone [1]. Previous studies have shown that certain areas of the country experience higher rates of work-related injuries and fatalities compared to others, with the southeastern U.S. being the most affected [2]. West Virginia (WV), a southeastern Appalachian state, has one of the highest fatal occupational injury rates in the country. In 2017, WV’s fatal occupational injury rate was the fourth highest among states at twice the national average (e.g. 7.4 per 100,000 vs. 3.5 per 100,000 full-time equivalent workers nationally) [1]. WV’s economy is heavily dependent on the mining, logging, and transportation industries, which also happen to be some of the most dangerous occupational sectors [1, 3, 4].

While work-related injuries and fatalities are caused by a myriad of reasons, transportation-related incidents account for a vast majority (e.g. 40%) of occupational-related deaths nationally [4]. Previous studies have found that law enforcement, construction workers, mining, natural gas/oil extraction workers, and truck drivers are more likely to die in motor vehicle collisions while on the job [5–11]. Previous studies specifically of WV workers have also found that transportation incidents were the leading cause of work-related death [12]. Numerous studies and systematic reviews have elucidated risk and protective factors associated with occupational-related motor vehicle collisions including extended work shifts, vehicle defects, vehicle type or configuration, drivers’ health, driver fatigue, drivers’ drug and alcohol use, drivers’ age and sex, the amount the employee drives, occupational stress, the type of road the employee drives, and the time of day [10, 11, 13–21]. Other studies of commercial truck drivers have found that many individuals speed and violate Hours of Service regulations in order to meet perceived unrealistic delivery schedules [15].

Despite the known risk factors associated with occupational injuries/fatalities resulting from motor vehicle collisions, driving in Appalachia, especially for work, may be inherently dangerous. West Virginia is the only state to lie completely within the Appalachian region. Previous studies have shown that the traffic fatality rate in Appalachia and WV is 40% and 70% higher, respectively, than the national rate [22, 23]. The fatality rate in WV for large trucks, which are typically driven only for work, is nearly 1.75 times higher than the national average [23]. While the exact reason for this disparity in WV is unknown, several studies have proposed potential explanations. Seat belt usage in Appalachia is known to be lower than the rest of the country [24]. Previous studies have also suggested that drivers’ speeding, lower seat belt use, and drivers’ increased drug and alcohol use may contribute to the elevated traffic fatality rates [25]. Another study has suggested that drivers’ opioid use, which is particularly elevated in the WV population, as a potential risk factor for collision [26]. Other factors such
as the state’s curvy topography, rurality, geographic isolation, and distance to emergency medical care may compound WV’s high fatality rates [23, 24].

Because motor vehicle collisions are the biggest contributor of occupational-related fatalities both nationally and in WV, the purpose of this study was to assess the characteristics of work-related crashes compared to non-work-related collisions in WV. The objective was to discern what factors predict work-related crashes and to determine where they most often occur within the state. Additional analyses were conducted to compare driver, vehicle, and crash characteristics of in-state vs. out-of-state drivers who were killed in work-related collisions. It was hypothesized that out-of-state drivers may be fundamentally different from in-state drivers as they may be unfamiliar with WV’s rurality, geography, and road systems. Previous studies have shown that rural collisions and individuals holding out-of-state drivers’ licenses are more likely to be killed in crashes [17, 27]. These findings could potentially inform public safety initiatives or employer safety programs.

Materials and methods

Subjects

Data were obtained from the Fatality Analysis Reporting System (FARS). FARS is a publicly available national database maintained by the National Highway Traffic Safety Administration (NHTSA). FARS is a compilation of all fatal crashes which occur on U.S. public roadways where any individual whom is involved in the crash dies within 30 days of the incident. All states and U.S. territories contribute to FARS. FARS contains well over 100 variables pertaining to circumstances surrounding the crash, vehicles, and any individual involved. FARS has been described previously in detail elsewhere [28, 29].

The study population was limited to any individual (i.e. driver, pedestrian, or passenger) \( \geq \) 18 years of age who was fatally injured in a motor vehicle collision within WV’s state boundary from Jan 1, 2000 to December 31, 2017. The purpose of limiting the age range was because no individual who was considered ‘at work’ at time of collision was < 18 years of age. This study was approved by West Virginia University’s Institutional Review Board.

Data management

Numerous independent variables were created using the FARS data (Table 1). These specific variables were chosen based on findings from previous transportation and/or occupational research [10, 11, 13–21]. With regards to race, the “Other” category included any individual deemed non-Caucasian by first responders. An individual was considered to have a commercial drivers’ license (CDL) regardless if it was current, suspended, or revoked at time of collision. Individuals were considered to be wearing a safety belt regardless if it was a shoulder and lap harness, lap only, or shoulder only at time of collision. The body type of the vehicle involved in the collision was categorized as a large truck, light truck or van, or passenger car based on NHTSA’s recommended categorization [28]. Vehicle age was determined by subtracting the year of the crash from the model year of the vehicle the person was driving at time of crash. Air bags were considered to be deployed (yes/no) regardless if it was the front and/or side air bags that deployed during the crash. Individuals were considered ‘ejected’ whether they were fully or partially ejected from the vehicle during the collision. An individual was considered to be positive for alcohol if their blood alcohol concentration was \( \geq 0.01 \text{ g/ml} \). An individual was considered drug positive if their toxicology tests detected any substance. Individual drugs and drug categories were also reviewed. An individual was categorized as having been cited (yes/no) for a traffic violation within the past 5 years. This included previous collisions, license suspensions, driving while intoxicated convictions, speeding tickets, or any other
Table 1. Characteristics of individuals ≥18 years of age who were fatally injured in motor vehicle collisions by work status in West Virginia, 2000–2017 (N = 5,835)*.

| Characteristic                     | Work-related | Non-work-related | Total     |
|-----------------------------------|--------------|------------------|-----------|
|                                   | N            | %                | N         | %        | N         | %        |
| Person type                        |              |                  |           |          |           |          |
| Driver                            | 177          | 84.7             | 4,180     | 74.3     | 4,357     | 74.7     |
| Passenger                         | 16           | 7.6              | 1,094     | 19.5     | 1,109     | 19.0     |
| Pedestrian                        | 16           | 7.7              | 352       | 6.3      | 369       | 6.3      |
| Male                              |              |                  |           |          |           |          |
| Yes                               | 198          | 94.7             | 3,970     | 70.6     | 4,168     | 71.4     |
| No                                | 11           | 5.3              | 1,656     | 29.4     | 1,667     | 28.6     |
| Age group (years)                 |              |                  |           |          |           |          |
| 18–34                             | 42           | 20.1             | 2,171     | 38.6     | 2,213     | 37.9     |
| 35–54                             | 109          | 52.2             | 1,796     | 31.9     | 1,905     | 32.7     |
| ≥55                               | 58           | 27.8             | 1,659     | 29.5     | 1,717     | 29.4     |
| Race                              |              |                  |           |          |           |          |
| White                             | 190          | 91.4             | 5,455     | 97.2     | 5,645     | 97.0     |
| Other                             | 18           | 8.7              | 158       | 2.8      | 176       | 3.0      |
| Missing                           | 1            | 1                | 13        |          | 14        |          |
| Commercial drivers' license       |              |                  |           |          |           |          |
| Yes                               | 131          | 70.0             | 568       | 10.8     | 699       | 12.9     |
| No                                | 56           | 30.0             | 4,684     | 89.2     | 4,740     | 87.1     |
| Missing                           | 22           |                  | 374       |          | 396       |          |
| Safety belt in use                |              |                  |           |          |           |          |
| Yes                               | 66           | 44.9             | 1,471     | 35.6     | 1,537     | 35.9     |
| No                                | 81           | 55.1             | 2,663     | 64.4     | 2,744     | 64.1     |
| Missing                           | 62           |                  | 1,492     |          | 1,554     |          |
| Driver's license state            |              |                  |           |          |           |          |
| West Virginia                     | 93           | 48.4             | 4,311     | 81.9     | 4,404     | 80.7     |
| Outside of West Virginia          | 99           | 51.6             | 956       | 18.1     | 1,055     | 19.3     |
| Missing                           | 17           |                  | 359       |          | 376       |          |
| Vehicle type                      |              |                  |           |          |           |          |
| Large truck                       | 130          | 62.2             | 10        | 0.2      | 140       | 2.4      |
| Light truck or van                | 49           | 23.4             | 1,982     | 35.3     | 2,031     | 34.8     |
| Passenger car                     | 11           | 5.3              | 2,462     | 43.8     | 2,473     | 42.4     |
| Other                             | 19           | 9.1              | 1,166     | 20.8     | 1,185     | 20.3     |
| Missing                           | 0            | 0                | 6         |          | 6         |          |
| Vehicle ≥ 10 years of age         |              |                  |           |          |           |          |
| Yes                               | 47           | 22.5             | 2,135     | 37.9     | 2,182     | 37.4     |
| No                                | 162          | 77.5             | 3,491     | 62.1     | 3,653     | 62.6     |
| Airbag deployed                   |              |                  |           |          |           |          |
| Deployed                          | 15           | 9.3              | 1,054     | 22.2     | 1,069     | 21.8     |
| Not deployed                      | 146          | 90.7             | 3,685     | 77.8     | 3,831     | 78.2     |
| Missing                           | 48           |                  | 887       |          | 935       |          |
| Victim ejected during crash       |              |                  |           |          |           |          |
| Ejected                           | 52           | 27.2             | 1,439     | 29.4     | 1,491     | 29.3     |
| Not ejected                       | 139          | 72.8             | 3,459     | 70.6     | 3,598     | 70.7     |
| Missing                           | 18           |                  | 728       |          | 746       |          |
| Alcohol detected                  |              |                  |           |          |           |          |

(Continued)
Table 1. (Continued)

| Characteristic                  | Work-related | Non-work-related | Total |
|---------------------------------|--------------|------------------|-------|
|                                 | N  | %   | N  | %   | N  | %   |
| Yes                             | 8  | 4.2 | 1,820 | 36.2 | 1,828 | 35.1 |
| No                              | 184 | 95.8 | 3,204 | 63.8 | 3,388 | 64.9 |
| Missing                         | 17 | 602  | 619  |       |       |       |
| Drug(s) detected                |    |      |      |       |       |       |
| Yes                             | 28 | 14.7 | 1,565 | 31.7 | 1,593 | 31.1 |
| No                              | 162 | 85.3 | 3,368 | 68.3 | 3,530 | 68.9 |
| Missing                         | 19 | 693  | 712  |       |       |       |
| Traffic citation < 5 years     |    |      |      |       |       |       |
| Yes                             | 76 | 40.0 | 1,979 | 38.0 | 2,055 | 38.1 |
| No                              | 114 | 60.0 | 3,229 | 62.0 | 3,343 | 61.9 |
| Missing                         | 19 | 418  | 437  |       |       |       |
| Survival time after crash (minutes) |      |        |        |        |       |       |
| <2                              | 63 | 30.9 | 874  | 16.1 | 937  | 16.6 |
| 2–120                           | 118 | 57.8 | 3,214 | 60.2 | 3,332 | 59.1 |
| ≥120                            | 23 | 11.3 | 1,346 | 25.7 | 1,369 | 24.3 |
| Missing                         | 5  | 192  | 197  |       |       |       |
| Single vehicle crash            |    |      |      |       |       |       |
| Yes                             | 141 | 67.5 | 3,381 | 60.1 | 3,522 | 60.4 |
| No                              | 68  | 32.5 | 2,245 | 39.9 | 2,313 | 39.6 |
| Season (meteorological)         |    |      |      |       |       |       |
| Winter                          | 51 | 24.4 | 1,168 | 20.8 | 1,219 | 20.9 |
| Spring                          | 40 | 19.1 | 1,355 | 24.1 | 1,395 | 23.9 |
| Summer                          | 64 | 30.6 | 1,618 | 28.8 | 1,682 | 28.8 |
| Fall                            | 54 | 25.8 | 1,485 | 26.4 | 1,539 | 26.4 |
| Weekend                         |    |      |      |       |       |       |
| Yes                             | 23 | 12.0 | 1,750 | 33.2 | 1,773 | 32.4 |
| No                              | 169 | 88.0 | 3,524 | 66.8 | 3,693 | 67.6 |
| Missing                         | 17 | 352  | 369  |       |       |       |
| Night                           |    |      |      |       |       |       |
| Yes                             | 75 | 36.6 | 2,979 | 54.2 | 3,054 | 53.6 |
| No                              | 130 | 63.4 | 2,516 | 45.8 | 2,646 | 46.4 |
| Missing                         | 4  | 131  | 135  |       |       |       |
| Inclement weather               |    |      |      |       |       |       |
| Yes                             | 44 | 22.9 | 899  | 17.1 | 943  | 17.3 |
| No                              | 148 | 77.1 | 4,370 | 82.9 | 4,518 | 82.7 |
| Missing                         | 17 | 357  | 374  |       |       |       |
| Highway collision               |    |      |      |       |       |       |
| Yes                             | 175 | 83.7 | 3,766 | 67.0 | 3,941 | 67.6 |
| No                              | 34  | 16.3 | 1,859 | 33.0 | 1,893 | 32.4 |
| Missing                         | 0  | 1    | 1    |       |       |       |
| Number of lanes                 |    |      |      |       |       |       |
| 1                               | 1  | 0.5  | 45   | 0.9  | 46   | 0.8  |
| 2                               | 177 | 92.2 | 4,948 | 93.9 | 5,125 | 93.9 |
| ≥3                              | 14 | 7.3  | 276  | 5.2  | 290  | 5.3  |
| Missing                         | 17 | 357  | 374  |       |       |       |
| Vehicle rollover                |    |      |      |       |       |       |
(Continued)
type of traffic violation. Season when the collision occurred was based on the meteorological classification. Weekend collisions (yes/no) were those which occurred either on Saturdays or Sundays. Nighttime collisions were classified as those occurring anytime between 5:00 PM and 4:59 AM (yes/no). Weather conditions were considered inclement if any precipitation or excessive wind was occurring at time of the collision. Collisions were classified as to whether they occurred on a state or federally designated highway (yes/no). If there was evidence that the vehicle rolled over during the collision, this was binary coded (yes/no). If the collision occurred on a road with a speed limit \( \geq 55 \) miles per hour, this was considered a high-speed crash (yes/no). The roadway in which the crash occurred was also coded if it was straight or curved or level or sloped.

**Statistical analyses**

Separate multivariable logistic regression analyses were conducted to assess odds of fatal occupational and non-occupational related collision among drivers, and subsequent in-state vs. out-of-state fatal occupational related collisions among drivers. In order to determine what factors predicted these outcomes, a model building process was undertaken to identify the most parsimonious model. Binary relationships between each of the separate model outcomes and independent variables were assessed [30]. Any independent variable that was significant with work status at a p-value \( \leq 0.20 \) level in the binary models was considered for a multivariate logistic regression model [31]. Variables were kept or removed from the multivariate logistic model based on backward selection technique with the p-value \( \leq 0.15 \); this p-value was chosen as it has been shown to be the most effective among models using backward selection technique to ensure variables which are important to the model or are potential confounding variables remain within the model [32]. Akaike Information Criterion and Hosmer-Lemeshow

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**Table 1.** (Continued)

| Characteristic                        | Work-related | Non-work-related | Total |
|---------------------------------------|--------------|------------------|-------|
|                                       | N  | % | N | % | N | % |
|工作相关的 | | | | | | |
| Organic | 108 | 56.0 | 1,702 | 32.3 | 1,810 | 33.1 |
| No | 85 | 44.0 | 3,566 | 67.7 | 3,651 | 66.9 |
| Missing | 16 | | 358 | | 374 | |
| Speed limit road (\( \geq 55 \) miles per hour) | | | |
| Yes | 162 | 85.3 | 3,127 | 61.4 | 3,289 | 62.2 |
| No | 28 | 14.7 | 1,970 | 38.7 | 1,998 | 37.8 |
| Missing | 19 | | 529 | | 548 | |
| Road alignment | | | |
| Straight | 87 | 45.3 | 2,841 | 54.0 | 2,928 | 53.7 |
| Curve | 105 | 54.7 | 2,424 | 46.0 | 2,529 | 46.3 |
| Missing | 17 | | 361 | | 378 | |
| Road slope | | | |
| Level | 87 | 45.3 | 3,066 | 58.3 | 3,153 | 57.8 |
| Grade | 99 | 51.6 | 1,935 | 36.8 | 2,034 | 37.2 |
| Hillcrest | 4 | 2.1 | 215 | 4.1 | 219 | 4.1 |
| Sag (Bottom of hill) | 2 | 1.0 | 46 | 0.9 | 48 | 0.9 |
| Missing | 17 | | 364 | | 381 | |

* Percentages may not add to 100% due to rounding.

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Goodness-of-Fit test were assessed to evaluate model fit. All statistical analyses were conducted using SAS software version 9.4 (Cary, North Carolina).

For spatial analysis, geographic patterns of work and non-work-related crashes were analyzed separately using dot density maps and isotropic kernel density estimation (KDE) using each event’s latitude and longitude and a WGS84 projection in the spatstat R package [33]. Briefly, KDE is a non-parametric statistical approach for extrapolating point data over larger geographic areas, and useful in limiting bias due to Modifiable Areal Unit Problems [34]. Point density functions, or intensity, was calculated using a fixed bandwidth with a Gaussian kernel, and included the Jones-Diggle improved edge correction shown to reduce distortion of density estimates nearer to the boundary, which in this case was the WV state boundaries [35, 36]. Adaptive and fixed bandwidths for KDE analyses have been explored in previous public health research [34, 37, 38]. In general, fixed bandwidths are ideal where estimating density an event, but are potentially insufficient for risk estimation particularly in sparsely populated areas [34, 39, 40]. For this study, the primary concern was geographic distance and number of events (e.g. not risk), therefore fixed bandwidth appropriately represents density of work and non-work-related crashes [34].

Results

There were 5,835 individuals fatally injured in motor vehicle collisions which occurred on WV roads from 2000–2017 (Table 1). Among these individuals, 209 (3.6%) were fatally injured while ‘at work’ and the majority of individuals were drivers (84.7%) of the vehicles involved. Most fatally injured workers were white (91.4%), males (94.7%), and aged 35–54 years (52.2%) which contrasted slightly from non-workers whom tended to be younger (38.6%). The majority of workers held a CDL (70%) and 48% were WV residents. While most of those involved in non-work-related collisions were occupants of either passenger cars (43.8%) or light trucks/vans (35.3%), most workers were occupants of large trucks, which includes tractor trailers (62.2%). While safety belt usage rates were low for both workers and non-workers, workers tended to use safety belts slightly more (44.9% for workers vs. 35.6% for non-workers). Compared to non-workers, those killed in work-related crashes tended to test positive less for drugs (14.7%) and alcohol (4.2%). Those ‘at work’ tended to expire quicker than non-workers with nearly 31% dying on impact compared to 16% for non-workers. However, vehicles carrying workers tended to be newer as only 22.5% of these vehicles were ≥10 years of age. In general, fatal crashes occurred more frequently during the week (e.g. Monday-Friday). While work-related crashes occurred mostly during the day (63.4%), non-work-related crashes were mostly at nighttime (54.2%). Weather was a factor in 23% of work-related crashes as opposed to 17% non-work collisions. Regardless of work status, most of the fatal crashes occurred on highways. However, highway collisions were more frequent in work-related crashes (84%) compared to non-work-related crashes (67.0%). A curved road alignment was the slightly more common setting of work-related crashes (54.7%), while a straight road alignment was the more common for non-work-related crashes (54.0%). While work-related crashes occurred with greater frequency on a grade (51.6%) than other road slopes, a grade was less common for non-work-related crash fatalities (36.8%).

Work-related vs. non-work-related crashes

Differences in the odds of fatal collision for drivers involved in work vs. non work-related collisions are highlighted in Table 2. The odds of being a work-related fatal collision was predicted by drivers’ sex, alcohol and drug test status, commercial driver’s license status, type of vehicle driven, number of vehicles involved, weather at time of crash, and vehicle age, which
explained 59% of the variance (e.g. Max rescaled R square). The Akaike Information Criteria improved (e.g. decreased indicating better fit) from the initial to final model (i.e. from 410.4 to 392.3, respectively) and the Hosmer Lemeshow Goodness-of-Fit test indicated acceptable fit (p = 0.2171) of the final model. However, only alcohol test status, having a commercial driver’s license, vehicle type, weather, and vehicle age remained statistically significant (i.e. p < 0.05) in the final model. The odds of being a work-related fatality were 85% lower for those testing positive for alcohol (0.15; 95% CI: 0.04, 0.49) compared to those who did not. Additionally, the odds of being a work-related fatality were 2.5 greater for individuals holding a CDL (OR = 2.56; 95% CI: 1.16, 5.65) and 2.5 times greater (OR = 2.51; 95% CI: 1.30, 4.83) for those driving in inclement weather. However, the odds of being a work-related fatality were 65% lower for individuals driving an older vehicle as well (OR = 0.35; 95% CI: 0.16, 0.77).

### In-state vs. out-of-state work-related crashes

Factors associated with in-state work-related collisions are displayed in Table 3. The odds of being an in-state driver were 75% lower (OR = 0.25; 95% CI: 0.12, 0.53) for those wearing a safety belt. Additionally, the odds of being an in-state driver were 2.7 times greater (OR = 2.67; 95% CI: 1.10, 6.52) among those testing drug positive. Among in-state drivers, narcotics were the most common drug identified (N = 12; 63%). The odds of being an in-state driver were

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Table 2. Factors that predict fatal work-related vs. non-work-related motor vehicle collisions among drivers in West Virginia, 2000–2017.

| Factor                      | Odds Ratio | 95% Confidence Interval |
|-----------------------------|------------|-------------------------|
| Sex                         |            |                         |
| Male                        | 2.25       | 0.92, 5.52              |
| Female                      | 1.00       | Referent                |
| Alcohol positive            |            |                         |
| Yes                         | 0.15       | 0.04, 0.49              |
| No                          | 1.00       | Referent                |
| Drug positive               |            |                         |
| Yes                         | 0.56       | 0.25, 1.19              |
| No                          | 1.00       | Referent                |
| Commercial drivers’ license |            |                         |
| Yes                         | 2.56       | 1.16, 5.65              |
| No                          | 1.00       | Referent                |
| Vehicle type                |            |                         |
| Passenger car               | 0.001      | 0.001, 0.003            |
| Light truck/van             | 0.005      | 0.001, 0.02             |
| Large truck                 | 1.00       | Referent                |
| Other                       | 0.003      | 0.001, 0.02             |
| Single-vehicle collision    |            |                         |
| Yes                         | 0.61       | 0.32, 1.16              |
| No                          | 1.00       | Referent                |
| Inclement weather           |            |                         |
| Yes                         | 2.51       | 1.30, 4.83              |
| No                          | 1.00       | Referent                |
| Vehicle age > 10 years      |            |                         |
| Yes                         | 0.35       | 0.16, 0.77              |
| No                          | 1.00       | Referent                |

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Table 3. Factors associated with in-state drivers whom were fatally injured in work-related motor vehicle collisions in West Virginia, 2000–2017.

| Factor                          | Odds Ratio | 95% Confidence Interval |
|---------------------------------|------------|-------------------------|
| Sex                             |            |                         |
| Male                            | 0.37       | 0.07, 1.98              |
| Female                          | 1.00       | Referent                |
| Race                            |            |                         |
| White                           | 16.05      | 2.06, 124.9             |
| Other                           | 1.00       | Referent                |
| Age                             |            |                         |
| 18–34                           | 1.54       | 0.69, 3.46              |
| 35–54                           | 1.00       | Referent                |
| ≥55                             | 1.92       | 0.97, 3.80              |
| Restraint use                   |            |                         |
| Yes                             | 0.25       | 0.12, 0.53              |
| No                              | 1.00       | Referent                |
| Alcohol positive                |            |                         |
| Yes                             | 3.00       | 0.59, 15.32             |
| No                              | 1.00       | Referent                |
| Drug positive                   |            |                         |
| Yes                             | 2.67       | 1.10, 6.52              |
| No                              | 1.00       | Referent                |
| Commercial drivers’ license     |            |                         |
| Yes                             | 0.26       | 0.13, 0.53              |
| No                              | 1.00       | Referent                |
| Large truck                     |            |                         |
| Yes                             | 0.18       | 0.09, 0.37              |
| No                              | 1.00       | Referent                |
| Single-vehicle collision        |            |                         |
| Yes                             | 0.47       | 0.25, 0.88              |
| No                              | 1.00       | Referent                |
| Weekend                         |            |                         |
| Yes                             | 0.34       | 0.13, 0.92              |
| No                              | 1.00       | Referent                |
| Inclement weather               |            |                         |
| Yes                             | 0.86       | 0.42, 1.75              |
| No                              | 1.00       | Referent                |
| Nighttime collision             |            |                         |
| Yes                             | 0.50       | 0.27, 0.93              |
| No                              | 1.00       | Referent                |
| Citation history                |            |                         |
| Yes                             | 0.73       | 0.40, 1.34              |
| No                              | 1.00       | Referent                |
| Highway collision               |            |                         |
| Yes                             | 0.22       | 0.06, 0.79              |
| No                              | 1.00       | Referent                |
| Roll-over collision             |            |                         |
| Yes                             | 0.86       | 0.47, 1.56              |
| No                              | 1.00       | Referent                |
82% (OR = 0.18; 95% CI: 0.09, 0.37) and 53% lower (OR = 0.47; 95% CI: 0.25, 0.88) among those driving a large truck or being involved in a single vehicle collision, respectively. In-state drivers were less likely to be fatally injured on weekends, at night, or on the highway.

**Spatial analysis of work-related vs. non-work-related collisions**

Dot density (left panels) and Kernel Density Estimation maps (right panels) are shown in Fig 1. Overall, there were more non-work-related crashes than work-related shown by the frequency of red “+” in the dot maps. For both types of crashes, density of dots clustered in south-central and in the northeastern regions of West Virginia. Despite generalities in point densities between crash types, work-related crashes had a relatively higher occurrence in southern and north central WV, indicated by bright yellow spots, as opposed to a single area of emphasis in the northeastern panhandle observed for non-work-related crashes.

**Discussion**

The principle findings of this analysis were that fundamental differences existed not only between work-related and non-work-related fatal collisions which occurred in WV, but also among the in-state and out-of-state workers who were killed in these crashes. In general, the work-related collisions involved mostly middle-aged, non-impaired drivers of large trucks who were involved in single-vehicle collisions, on highways, during the daytime on weekdays. Non-work-related fatalities mostly involved younger occupants of passenger cars, light trucks, and vans. This analysis also revealed the existence of two major populations of workers killed on WV roadways. One population consisted of long-haul truck drivers, who were mostly non-WV residents. The other consisted of workers involved in local transport who were mostly residents of the state. While non-resident truck drivers made up a larger proportion of the work-related fatalities, workers who were residents of WV were found to have important risk factors for being fatally injured on the road. Resident workers were more likely to not wear a seatbelt, and were more likely to test positive for drugs, which has important workplace safety implications.

The findings of this analysis concerning work-related collisions were somewhat expected and supported by the extant literature. Previous U.S. studies have also determined that most work-related transportation fatalities involve white, male drivers between 25–55 years of age, driving large trucks on highways during daytime hours [10]. Previous national and international studies have also found that drivers killed on the job are generally not impaired by alcohol [13, 41]. Mandatory alcohol testing for large truck drivers by the Federal Motor Carrier Safety Administration (FMCSA) has resulted in a significant decline in the rate of alcohol involvement in fatal, U.S., large truck crashes [42]. It was also expected that workers were

| Table 3. (Continued) |
|----------------------|
| Factor               | Odds Ratio | 95% Confidence Interval |
| Road curvature       |            |                         |
| Curved               | 0.59       | 0.32, 1.08              |
| Straight             | 1.00       | Referent                |
| Vehicle age > 10 years |          |                         |
| Yes                  | 2.44       | 1.18, 5.06              |
| No                   | 1.00       | Referent                |

*: N = 177; in-state drivers = 87; out-of-state drivers = 90

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more likely to experience their collisions during inclement weather. In a 2010 survey conducted by the National Institute of Occupational Safety and Health of long-haul truck drivers, 24% of respondents said that they continued to drive despite fatigue, bad weather, or heavy traffic in order to meet timetables for the transport of loads. While traffic tends to decrease during adverse weather events, workers probably tended to stay on the roads to meet work demands while those driving for other purposes avoided this situation [43].

However, some findings of this analysis, especially those concerning the prevalence of single vehicle collisions and workers’ drug use, were slightly different than expected, but also explainable. Previous national studies of fatal work-related crashes have shown that multi-vehicle incidents are more prevalent than single vehicle collisions [10]. Previous literature has also found that workers driving large trucks are more likely to be killed in single-vehicle crashes, while occupants of smaller work vehicles are more likely to be killed in multiple vehicle collisions [11]. The reason why there were more single-vehicle collisions in WV could be due to having a higher proportion of large truck crashes in addition to the state’s topography and road systems. WV is mountainous and many roads—including highways—are narrow, steep, and curved. A large proportion of the work-related crashes occurred on grades and curved roads. While the cause of these collisions were often unknown, these drivers, who may be unfamiliar with WV’s roads, could easily have missed turns or ran off roads, which are common occurrences in single-vehicle collisions involving trucks [44].

As for drivers’ drug use, the high prevalence of stimulant use among truck drivers has been extensively studied in literature [45]. However, drug use was generally low among workers killed in WV and stimulant use was uncommon. Only in-state workers tended to test positive for drugs, but primarily for opioids. Drug use among large truck drivers may be lower due to tighter safety regulations, the institution of mandatory random drug screens, and hours of service restrictions. The prevalence of narcotics among in-state workers is likely due to the states’ high opioid use [26]. Opioids are one category of drugs known to negatively impact driving ability and crash rates [46].

While studies concerning in-state and out-of-state drivers are sparse in the extant literature, this analysis found that there are likely two distinct types of workers on WV roads. In contrast
to out-of-state workers whom mainly drove large trucks, in-state workers tended to drive older, smaller vehicles, not hold a commercial driver’s license, and be involved in multiple vehicle collisions, on non-highways, during the daytime on weekdays. Thus, these results suggest that in-state drivers are likely driving more regionally and out-of-state drivers are likely carrying larger loads and potentially travelling greater distances. From a workplace safety perspective, these findings have numerous implications. For example, seatbelt usage was low for all fatally injured workers regardless of residence status, but more so for in-state residents; workplace safety policies or education of workers may be greatly needed as seatbelts are known to save lives. Additionally, employers of long-haul drivers may need to advise newer drivers/employees who travel on WVs roads and may be unfamiliar of the risk of collision considering the amount of crashes occurring in the northern and southern regions of the state.

Protocols regarding inclement weather may also be needed as many large truck drivers met their demise during these episodes. Employers should consider adopting standard protocols for these situations and permit changes to operations and give drivers the ability to make decisions regarding the safety of the driving conditions without financial penalty. Moreover, this analysis revealed that the focus of work-related motor vehicle crash prevention efforts in WV should not focus solely on those who drive large trucks. The trucking industry is heavily regulated by the FMCSA and significant improvements to vehicle safety, drug and alcohol testing practices, and limitations on driving hours have been made. These regulations, however, do not apply to drivers of smaller vehicles that do not require a CDL, which was the case for many in-state workers. Also, due to the amount of drug positive resident workers, companies employing drivers of smaller fleet vehicles may want to consider random or mandatory drug testing programs. Currently, these practices exist for large trucking operations. In 2018, the FMCSA began to test for certain semi-synthetic opioid (e.g. hydrocodone, hydromorphone, oxycodone, and oxymorphone) in urine drug screens [47]. The detection of any scheduled controlled substance without a prescription disqualifies a driver operating a commercial motor vehicle. However, a letter from the prescribing physician assuring that the driver is safe to operate a commercial motor vehicle while a driver is taking an impairing medication as directed is sufficient to waive this disqualification [47]. Thus, even physicians who care for patients who drive smaller, non-commercial vehicles for work may want to consider advising their patients on the safety of certain medications known to affect driving ability.

Limitations

While this was the first study to investigate in-state and out-of-state drivers involved in fatal work-related collisions in WV and crash location spatially, this analysis is not without limitation. For example, there are well-known limitations of drug and alcohol test results in FARS which have been described in detail [48]; however, WV is one of the best states for conducting and reporting drug and alcohol test results on individuals and has one centralized Medical Examiner’s Office [25]. Secondly, the FARS data do not provide details regarding the occupation/industry of those fatally injured. This information would illuminate more details regarding occupational risk factors for road fatalities in WV. While these data are available in the Census of Fatal Occupational Injuries (CFOI) database maintained by the U.S. Bureau of Labor Statistics, only limited statistics are publicly available. Previous studies have shown ~90% of work-related fatality cases in FARS are also found in the CFOI database [49]. Thus, the number of work-related crash fatalities may be underestimated. Thirdly, it is possible that some individuals would be incorrectly identified by crash investigation personnel as ‘not at work’ while they were ‘at work’ at time of crash; this is more likely to occur in a situation where the worker was not driving a large truck or bus, and was not wearing a uniform [11, 49].
Fourthly, this study may not capture transportation incidents which occurred outside of public roadways. Approximately 15% of occupational transportation fatalities occur on non-public roadways [4]. Occupational fatalities due to all-terrain vehicles and trucks on private property have been described in WV. Notably, several deaths have been recorded due to workers being struck by haul trucks on private mine roads [8, 9, 19]. Additionally, due to the cross-sectional nature of this study, causality cannot be determined. Lastly, because more drivers were involved in fatal work-related single vehicle collisions, the actual cause of the crash was often unknown.

Conclusions
This study determined that work-related crashes differed greatly from non-work-related crashes in WV. These collisions also occurred in slightly different areas of the state; future studies could involve spatio-temporal modeling to discern or potentially explain why these patterns exist. Moreover, there were stark differences between in-state and out-of-state drivers killed in these collisions highlighting two distinct types of workers and subsequent crashes. Various avenues for workplace safety interventions exist, including seatbelt initiatives and drug testing policies of non-commercial drivers, which could help mitigate WV’s exorbitantly high occupational-related traffic fatality rate.

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