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Association between commercial vehicle driver at-fault crashes involving sleepiness/fatigue and proximity to rest areas and truck stops

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ABSTRACT

Introduction: There is ongoing concern at the national level about the availability of adequate commercial vehicle rest areas and truck stops for commercial vehicle drivers to rest or to wait for a delivery window.
Methods: A retrospective case-control study was conducted to determine the association between the occurrence of sleepiness/fatigue-related (cases) vs. all other human factor-related commercial vehicle driver at-fault crashes (controls) and proximity to rest areas, weigh stations with rest havens, and truck stops.
Results: Commercial vehicle driver at-fault crashes involving sleepiness/fatigue were more likely to occur on roadways where the nearest rest areas/weigh stations with rest havens/truck stops were located 20 miles or more from the commercial vehicle crash site (Odds Ratio [OR] = 2.32; Confidence Interval [CI] 1.615, 3.335] for 20–39.9 miles vs. < 20 miles; and OR = 6.788 [CI 2.112, 21.812] for 40+ miles) compared to commercial vehicle at-fault driver crashes with human factors other than sleepiness/fatigue cited in crash reports. Commercial vehicle driver at-fault crashes involving sleepiness/fatigue also were more likely to occur on parkways compared to interstates (adjusted OR = 3.747 [CI 2.83, 4.95]), during nighttime hours (adjusted OR = 6.199 [CI 4.733, 8.119]), and on dry pavement (adjusted OR 1.909, [CI 1.373, 2.655]).
Conclusions: The use of statewide crash data analysis coupled with ArcGIS mapping capabilities provided the opportunity to both statistically determine and to visualize the association between rest area/weigh station with rest haven/truck stop distance and the occurrence of commercial vehicle driver at-fault crashes involving sleepiness/fatigue. Implementation and evaluation of commercial vehicle employer policies and interventions such as the use of commercial vehicle driver fatigue alert systems may help to reduce fatigue and sleepiness in commercial vehicle drivers. These results can be used by state and local highway transportation officials to inform and increase truck parking availability, especially on parkways.

1. Introduction

It has been estimated that between 10% and 20% of all truck and bus crashes in the United States involve drivers who were fatigued at the time of the crash (National Academies of Sciences, Engineering, and Medicine, 2016). Driver physiological conditions such as diagnosed medical disorders that affect sleep, cause fatigue or alter sleep patterns (Chen et al., 2016; National Academies of Sciences, Engineering, and Medicine, 2016); workplace conditions (e.g., irregular hours due to just-in-time delivery requirements, and hours of service) (Chen et al., 2015; Sparrow et al., 2016; Chen and Xie, 2015); environmental conditions (e.g., rainy weather and nighttime driving) (Chen et al., 2015; Stevenson et al., 2014); and demographic factors such as age and driving experience (Meuleners et al., 2017; Bunn et al., 2005), may affect commercial vehicle driver patterns and behaviors, and result in driver sleepiness and fatigue that can increase roadway crash risk.

A number of countermeasures have been proposed to reduce commercial vehicle driver fatigue and commercial vehicle crash risk. Long-haul truck driver consumption of caffeinated beverages has been associated with reduced commercial vehicle crashes (Sharwood et al., 2013). Combined energy drink consumption as well as a rest break after 100 min of simulated driving reduced lane deviations and steering wheel deviations in professional truck drivers (Ronen et al., 2014). Also, installation of electronic logging devices in commercial vehicles was associated with reduced semi truck crash rates (Hickman et al., 2017). Last, regular rest breaks and driving schedules that do not include nighttime driving between midnight to dawn have been associated with reduced crash risk (Stevenson et al., 2014; Chen and Xie, 2013). These various types of countermeasures may help to improve scheduling and availability of suitable locations for breaks, that may

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reduce commercial vehicle driver fatigue, and inform and improve current hours of service regulations regarding restart breaks.

There is ongoing concern at the national level about the availability of adequate capacity for commercial vehicle rest areas and truck stops for commercial vehicle drivers to rest. Under the Federal Highway Administration Moving Ahead for Progress in the 21st Century Act of 2012: Jason's Law (Subtitle D. Highway Safety Sec. 1401), state surveys were conducted to assess current capacity, evaluate adequacy of commercial motor vehicle parking and rest facilities, and assess commercial motor vehicle traffic volume. According to the Federal Highway Administration, Kentucky ranked in the bottom half of states for the number of commercial vehicle truck parking spaces per 100,000 of daily combination vehicle miles traveled, and commercial vehicle truck parking problems were observed (Federal Highway Administration, 2015).

There is a paucity of research on the association between the availability of roadway rest areas, truck stops, and weigh stations with rest havens, and commercial vehicle driver at-fault crashes involving fatigue and sleepiness. The purpose of the current study was to conduct a retrospective case-control study to 1) characterize and compare sleepiness/fatigue-related vs. all other human factor-related commercial vehicle driver at-fault crashes; 2) map geographical locations of available private and public rest areas, truck stops, and weigh stations with rest havens on federal authorized truck routes; 3) examine the association between at-fault commercial vehicle driver crashes involving fatigue and/or sleepiness, and distances to nearest rest areas/truck stops/weight stations with rest havens, on roadways; and 4) map geographical locations of rest areas/truck stops/weigh stations with rest havens, relative to commercial vehicle driver at-fault crashes involving sleepiness/fatigue vs. commercial vehicle driver at-fault crashes involving all other human factors.

2. Methods

2.1. Study data

Kentucky commercial vehicle driver crash data for years 2005–2014 was obtained from the Kentucky Collision Report Analysis for Safer Highways (CRASH) system maintained by the Kentucky State Police that contains all reported crashes on public roadways in Kentucky. The electronic file received contained all motor vehicle crash information but excluded some personal identifiers. The study is part of the broad spectrum of the Kentucky Occupational Safety and Health surveillance program which is approved by the University of Kentucky Institutional Review Board.

2.2. Case-control study selection criteria

For purposes of this study, "commercial vehicles" included single unit trucks, semi-trucks, trucks and trailers, and other combination trucks. Selection criteria of cases and controls included: 1) commercial vehicles (unit types 21–24 in CRASH data); 2) unit number 1 (customarily considered the at-fault vehicle based on the officer's opinion); 3) person type = driver in driver's position; 4) vehicle not in parking lot; 5) pre-collision action not "parked" or "backing&rdquo"; and 6) human factor(s) listed in CRASH report (Kentucky State Police Records Section, 2000). Those cases with human factor code = 99 (no factors) were excluded from analysis.

This study utilized a case-control design that is effective when relatively rare outcomes and their determinants are studied. The outcome of interest was the human factor (sleepiness/fatigue vs any other human factor) contributing to a motor vehicle crash among at-fault commercial vehicle drivers involved in commercial vehicle crashes. *Cases* were defined as those at-fault commercial vehicle drivers in crashes where sleepiness and/or fatigue were listed as factor(s) in the crash reports. *Controls* were defined as those at-fault commercial vehicle drivers in involved in crashes where other possible human factors (alcohol involvement; cell phone; disregard traffic control; distraction; drug involvement; emotional; exceeded stated speed limit; failed to yield right of way; following too close; improper backing; improper passing; inattention; lost consciousness/fainted; medication; misjudge clearance; not under proper control; overcorrecting/oversteering; physical disability; sick; too fast for conditions; turning improperly; weaving in traffic; racing; failed to keep proper lane; and other) were listed in the crash reports.

2.3. Statistical analysis

The goal of the study was to test the hypothesis that the probability for an at-fault commercial driver crash (that already occurred) involving sleepiness/fatigue (vs other human factor) increases with increased distance to rest areas. The exposure variable of interest was the measured distance from the commercial vehicle driver crash to the nearest rest area, truck stop, or weigh station with rest haven, including the distances measured straight ahead and measured including a U-turn. Rest areas and weigh stations with rest havens were identified through the Kentucky Transportation Cabinet rest area directory listing. Truck stops were identified using ArcGIS Business Analyst 2015 for businesses that matched truck stop descriptions within 25 miles of Kentucky's borders. The ArcGIS is a geographic information system that enables geospatial analysis of case-control crashes to the nearest rest area, weigh station, and truck stop along the road network. Identified truck stops were individually verified to ensure that the locations were actual truck stop locations. Rest area, truck stop, and weigh station with rest haven geo-coordinates were mapped using ArcGIS network analyst, version 10.3, and NAVTEQ 2014 street data (Fig. 1). Measured rest area, truck stop, and weigh station with rest haven distances to commercial vehicle driver at-fault crash locations were categorized into three distances: 1) less than 20 miles; 2) at least 20 miles but less than 40 miles; and 3) ≥40 miles from the rest area/truck stop/weigh station to the crash location.

The case-control analysis was restricted to interstates and parkways within the Kentucky Transportation Cabinet Designated National Network for trucks with at least one rest area, weigh station with a rest haven, or truck stop. Per Kentucky Regulatory Statue 177.830, an "interstate highway" means any highway, road, street, access facility, bridge, or overpass which is designated as a portion of the national system of interstate and defense highways as may be established by law, or as may be so designated by the Transportation Cabinet in the joint construction of the system by the Transportation Cabinet and the United States Department of Transportation, Bureau of Public Roads" and a "turnpike" means any road or highway or appurtenant facility constructed pursuant to the provisions of KRS 177.390–177.570, or pursuant to the provisions of any other definition of "turnpike" in the Kentucky Revised Statutes, or any other highway, road, parkway, bridge, or street upon which a toll or fee is charged for the use of motor vehicular traffic". Parkways in Kentucky are no longer tolled.

A multiple logistic regression model (SAS® PROC LOGISTIC) was used to obtain an adjusted odds ratio as an effect measure for the association between the outcome of interest (sleepiness/fatigue vs other human factor(s) for at-fault commercial driver collisions) and the exposure of interest (distance between the crash site and a rest area, weigh station, or truck stop) while accounting for other covariates (e.g., relevant exposures, possible confounders, and effect modifiers) (Allison, 1999). The dependent variable modeled was 1 if sleepiness/fatigue was listed as a human factor for the at fault commercial vehicle driver crash, and 0 if other human factor(s) were listed on the crash report. The following collision, roadway, and commercial vehicle driver factors were controlled for in the analysis: 1) total number of roadway lanes (1–2 vs. 2+); 2) time of day of crash (7am < collision time ≤ 6 p.m.) indicating daylight and nighttime hours; 3) roadway character (straight *vs.* curved) at location of crash; 4) commercial vehicle driver age

Fig. 1. Location of Truck Stops, Rest Areas, and Weigh Stations with Rest Havens on Interstates and Parkways within the Federal Authorized National Network for Trucks in Kentucky (2016).

categories (21–24 years of age, 25–54 years of age, and 55+ years of age); 5) roadway condition (dry vs. wet) at location of crash; and 6) roadway type (interstate *vs*. parkway) at location of crash.

To test for a bivariate association between driver, collision, roadway, and commercial vehicle risk factors; proximity to nearest rest area, weigh station, or truck stop; and the outcome of a sleepiness/fatigue-related at-fault commercial vehicle crash, chi-square tests were performed on the data. Three separate multiple logistic regression models were built. The first model tested for association between the outcome of interest (at-fault-driver commercial vehicle driver crash recorded as sleepiness/fatigue-related vs other human factor-related) and the exposure variable "distance from crash location to nearest rest area/truck stop/weigh station with rest haven" (< 20 miles, 20 miles-39.9 miles, 40+ miles) on the federal authorized National Network for trucks in Kentucky. The second model identified the specific roads that were associated with higher odds for sleepiness/fatigue-related at-fault-driver crash. The following roads were included in the regression analysis: Interstate-24, Interstate-64, Interstate-65, Interstate-71, Interstate-75, Audubon Parkway, Cumberland Parkway, Bluegrass Parkway, Pennyrile Parkway, Purchase Parkway, Western Kentucky Parkway, and William H. Natcher Parkway. The third regression model tested the hypothesis for association between the outcome of interest and the type of road (interstate vs parkway). Initial regression models included collision and roadway exposure factors that were bivariately significantly associated with the outcome at level of significance 0.1. The statistical analysis included a SAS® *proc logistic* with a stepwise selection procedure.

3. Results

Based on the selection criteria, the final 2005–2014 year data set contained 284 commercial vehicle at-fault driver crashes with contributing factor(s) of sleepiness/fatigue listed in the crash reports (cases) and 7254 commercial vehicle at-fault driver crashes with human factors other than sleepiness/fatigue cited in crash reports (controls). The final number of rest areas/truck stops on designated National Network's interstates and parkways totaled 88. Descriptive analysis (Table 1) showed no statistically significant differences between cases and controls for commercial vehicle driver age, and vehicle unit type. Statistically significant differences in proportions between cases and controls were observed for time of day, distance to nearest rest area/truck stop from commercial vehicle crash location, manner of collision, injury severity, and driver restraint use. Sleepiness/fatigue-related commercial vehicle driver crashes (cases) occurred more frequently during nighttime hours, and the crashes were primarily single vehicle crashes. There were higher percentages of possible, non-incapacitating, capacitating, and fatal injuries in the cases; and the cases more frequently involved lack of driver restraint use, compared to the control group. There was a higher proportion of sleepiness/fatigue-related commercial vehicle driver crash cases where the distance to the nearest rest area/truck stop from the crash location was 20–39.9 miles compared to the controls (14% of the cases compared to 6% of the controls).

When roadway characteristics of the at-fault commercial vehicle driver crashes were examined, the sleepiness/fatigue-related at-fault commercial vehicle driver crashes (cases) occurred more frequently on dry pavement and on parkways compared to the crashes of the control group (Table 2). There was no significant difference between the cases and controls for roadway character (straight vs. curved), or for the number of roadway lanes where the at-fault commercial vehicle driver crashes occurred. The proportion of at-fault commercial vehicle driver crashes involving sleepiness/fatigue (cases) that occurred on parkways was almost three times that of the controls (29% of cases vs. 9% of controls).

Higher numbers and percentages of case and control at-fault commercial vehicle driver crashes were observed on interstates in general compared to parkways (Fig. 2 and Table 2). Plotted geo-coordinates of at-fault commercial vehicle driver crashes show the largest proportions of sleepiness/fatigue-related commercial vehicle driver crashes (cases) and controls occurred on Interstate-65, Interstate-75, and Interstate-64 (56% of cases and 74% of controls). A larger number of at-fault commercial vehicle driver crashes that involved all other human factors were visually observed in and near the metropolitan areas of Louisville, Lexington, and northern Kentucky.

Results of the first logistic regression analysis showed that commercial vehicle driver at-fault crashes involving sleepiness/fatigue were more likely to occur on roadways where the nearest rest areas/weigh stations with rest havens/truck stops were located 20 miles or more from the commercial vehicle crash site (odds ratio [OR] = 2.45;

Table 1
Demographic and Crash Characteristics of Commercial Vehicle Driver At-fault Crashes in Kentucky, 2005–2014.

Characteristic	Cases (n = 284) (Human Factor = Sleepiness/Fatigue)	Controls (n = 7254) (Human Factor = all others)	Chi-Square
Commercial Vehicle Driver Age Category			$p = 0.0805$
21–24 years of age	8 (3%)	240 (3%)	
25–54 years of age	222 (78%)	5232 (72%)	
55+ years of age	54 (19%)	1782 (25%)	
Time of Day of Crash			$p < 0.0001$
Daytime (7 a.m.–6:69 p.m.)	76 (27%)	5026 (69%)	
Nightime (7 p.m.– 6:59 a.m.)	208 (73%)	2228 (31%)	
Commercial Vehicle Unit Type			$p = 0.8218$
Truck and trailer	51 (18%)	1245 (17%)	
Truck-single unit	28 (10%)	796 (11%)	
Truck tractor and semi-trailer	198 (70%)	5077 (70%)	
Truck-other combination	7 (2%)	136 (2%)	
Distance (in miles) to Nearest Rest Area/Weigh Station with Rest Haven/ Truck Stop from Commercial Vehicle Crash Site			$p < 0.0001$
< 20 miles	241 (85%)	6800 (94%)	
20–39.9 miles	39 (14%)	435 (6%)	
40+ miles	4 (1%)	19 (< 1%)	
Manner of Commercial Vehicle Collision			$p < 0.0001$
Angle	4 (1%)	219 (3%)	
Rear End/Rear to Rear	35 (12%)	2195 (30%)	
Sideswipe-Opposite Direction/Sideswipe-Same Direction	20 (7%)	3015 (42%)	
Single Vehicle	223 (79%)	1645 (23%)	
Other	2 (1%)	179 (2%)	
Commercial Vehicle Driver Injury Severity			$p < 0.0001$
Fatal injury	7 (2%)	55 (1%)	
Incapacitating injury	17 (6%)	103 (1%)	
Non-incapacitating injury	49 (17%)	295 (4%)	
Possible injury	41 (14%)	228 (3%)	
None	170 (60%)	6566 (91%)	
Commercial Vehicle Driver Restraint Use			$p < 0.0001$
No	18 (6%)	139 (2%)	
Yes	266 (94%)	7115 (98%)	

Table 2
Roadway Characteristics of Commercial Vehicle Driver At-fault Crashes in Kentucky, 2005–2014.

Characteristic	Cases (n = 284) (Human Factor = Sleepiness/Fatigue)	Controls (n = 7254) (Human Factor = all others)	Chi-Square
Roadway Character			$p = 0.8678$
Straight roadway	222 (78%)	5640 (76%)	
Curved roadway	62 (22%)	1614 (22%)	
Roadway Condition			$p = 0.0026$
Dry roadway	239 (84%)	5547 (76%)	
Wet roadway	45 (16%)	1707 (24%)	
Number of Roadway Lanes			$p = 0.4518$
1–2 lanes	49 (17%)	1381 (19%)	
> 2 lanes	235 (83%)	5873 (81%)	
Individual Roadway			$p < 0.0001$
Interstate-24	17 (6%)	329 (5%)	
Interstate-64	51 (18%)	1022 (14%)	
Interstate-65	60 (21%)	2178 (30%)	
Interstate-71	26 (9%)	880 (12%)	
Interstate-75	49 (17%)	2186 (30%)	
Audubon and Cumberland Parkways	5 (2%)	53 (7%)	
Bluegrass Parkway	14 (5%)	88 (1%)	
Pennyrile Parkway	25 (9%)	160 (2%)	
Purchase Parkway	8 (3%)	79 (1%)	
Western Kentucky Parkway	18 (6%)	184 (3%)	
William H. Natcher Parkway	11 (4%)	95 (1%)	
Roadway Type			$p < 0.0001$
Interstate highway	203 (71%)	6595 (91%)	
Parkway	81 (29%)	659 (9%)	

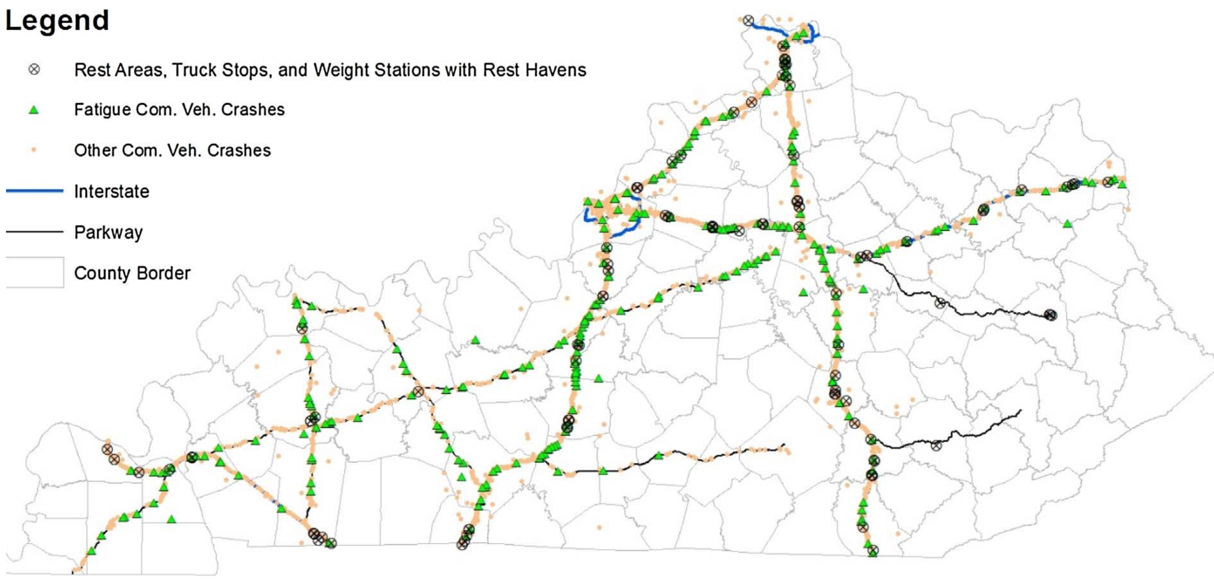

Fig. 2. Location of Commercial Vehicle Driver At-fault Crashes Relative to Proximity to Rest Areas/Weigh Stations with Rest Havens/Truck Stops in Kentucky, 2005–2014.

Table 3
Odds Ratios for Commercial Vehicle Driver At-fault Crashes Involving Sleepiness/Fatigue in Kentucky, 2005–2014.

Regression Model Number	Commercial Vehicle Crash Characteristic	Odds Ratio	95% CI ($p < 0.05$)
1	Nighttime vs. Daytime Hour of Commercial Vehicle Crash	6.308	4.820–8.256
	Rest Area/Weigh Station with Rest Haven/Truck Stop Distance of 20–39.9 Miles vs. < 20 Miles to Commercial Vehicle Crash Site	2.452	1.704–3.529
	Rest Area/Weigh Station with Rest Haven/Truck Stop Distance of 40+ Miles vs. < 20 Miles to Commercial Vehicle Crash Site	6.806	2.119–21.861
	Dry vs. Wet Roadway at Time of Commercial Vehicle Crash	1.917	1.380–2.661
2	Commercial Vehicle Crash Characteristic	Adjusted Odds Ratio	95% CI ($p < 0.05$)
	Nighttime vs. Daytime Hour of Commercial Vehicle Crash	6.524	4.965–8.572
	Dry vs. Wet Roadway at Time of Commercial Vehicle Crash	1.921	1.378–2.678
	Interstate-24 vs. Interstate-75	2.574	1.449–4.574
	Interstate-64 vs. Interstate-75	2.519	1.678–3.781
	Interstate-65 vs. Interstate-75	1.299	0.882–1.912
	Interstate-71 vs. Interstate-75	1.549	0.950–2.526
	Audubon Parkway vs. Interstate-75	15.256	3.135–74.238
	Bluegrass Parkway vs. Interstate-75	5.940	3.086–11.435
	Cumberland Parkway vs. Interstate-75	3.384	0.976–11.731
	Pennyrile Parkway vs. Interstate-75	7.260	4.278–12.320
	Purchase Parkway vs. Interstate-75	4.536	2.024–10.165
	Western Kentucky Parkway vs. Interstate-75	3.931	2.207–7.001
	William H. Natcher Parkway vs. Interstate-75	6.578	3.216–13.454
3	Crash Characteristic	Adjusted Odds Ratio	95% CI ($p < 0.05$)
	Nighttime vs. Daytime Hour of Commercial Vehicle Crash	6.199	4.733–8.119
	Parkway vs. Interstate	3.747	2.834–4.954
	Dry vs. Wet Roadway at Time of Commercial Vehicle Crash	1.909	1.373–2.655

Confidence Interval [CI] 1.704, 3.529) for 20–39.9 miles vs. < 20 miles; and OR = 6.806 [CI 2.119, 21.861] for 40+ miles) (Table 3). Visual inspection of the maps showed parkways were the primary roadways with the lowest densities of rest areas, weigh stations with rest havens, and truck stops compared to interstate roadways so the second logistic regression factor for "distance" was replaced with "specific roadway". Results showed individual parkways had much higher odds of at-fault commercial vehicle driver crashes involving sleepiness/fatigue so the interstates and parkways were each grouped together. The final logistic regression controlled for roadway type (interstate vs. parkway), and results showed commercial vehicle driver at-fault crashes involving sleepiness/fatigue were more likely to occur on parkways compared to interstates (adjusted OR = 3.747 [CI 2.83, 4.95]) (Table 3). At-fault commercial vehicle driver crashes involving sleepiness/fatigue also were more likely to occur during nighttime hours and on dry pavement, indicating adverse weather was not a contributing factor, and commercial vehicle driver nighttime rest is necessary to reduce sleepiness/fatigue-related commercial vehicle driver at-fault crashes. No significant effect modifications/interactions were present in any of the three models.

4. Discussion

The ArcGIS map showed that parkways on the federal designated National Network for trucks, in particular, are deficit in truck stops/rest areas. A Virginia Department of Transportation report published in November 2007 suggested increasing public rest area and commercial truck stop parking may help reduce commercial vehicle driver fatigue (Winter, 2007). We found a positive association between distance (in miles) to rest area/weigh station with rest haven/truck stop availability, and the occurrence of commercial vehicle driver at-fault crashes involving sleepiness/fatigue. In a Federal Highway Administration national survey administered to stakeholders, Kentucky ranked in the lower half of all states for total truck parking spaces (National Academies of Sciences, Engineering, and Medicine, 2016). Approximately three-quarters of the surveyed truck drivers reported problems with truck parking availability when they needed to rest, and 90% of the truck drivers reported truck parking availability issues during nighttime hours; truck parking availability on interstate highways vs. parkways was not delineated. Our results support the need for increased truck parking on the federally designated National Network for trucks, particularly on parkway routes. Existing rest areas should be expanded for additional truck parking and new truck rest areas should be established, particularly on parkways.

Our study also found an association between the occurrence of sleepiness/fatigue-related commercial vehicle driver at-fault crashes and driving during nighttime hours. These results confirm other naturalistic and simulated studies that showed an association between nighttime driving and increased sleepiness and fatigue, especially when the commercial vehicle drivers only had one nighttime period in their restart break (Sparrow et al., 2016; Van Dongen and Belenky, 2010; Van Dongen et al., 2010; Kazimierz and Smolarek, 2013). In a simulated driving study of drivers who were sleepy and who had an increased likelihood of crashing, the sleepy drivers were able to detect the indicators of oncoming sleepiness (Williamson et al., 2014). The results of this study confirm the authors' conclusions that commercial vehicle employers should consider two nighttime periods in their commercial vehicle drivers' restart breaks, and reinforce the need for commercial vehicle drivers to recognize and respond to sleepiness indicators by immediately parking and taking rest breaks.

Fatigue/sleepiness-related (case group) commercial vehicle driver injuries were more severe, occupant restraints were less frequently worn, and over three-quarters of the crashes involved single vehicles at the time of the crash compared to the control group in our study. These results confirm the results of other studies that found commercial vehicle driver sleepiness/fatigue, nonuse of safety belts, and single vehicle crashes are associated with increased risk of severe commercial vehicle driver injuries in crashes (Bunn et al., 2005; Bunn et al., 2012; Bunn et al., 2013). The Federal Motor Carrier Safety Administration requires the use of safety belts in commercial vehicle drivers and passengers (Subpart B §392.16). Although driver seat belt use compliance was high among the cases (94%, 18 commercial vehicle drivers) and controls (98%, 139 commercial vehicle drivers), regular reinforcement of the FMCSA seat belt policy is needed to further increase seat belt use compliance and to reduce commercial vehicle crash injury severity.

The following are limitations to the study: 1) possible underreporting of fatigue/sleepiness in crash reports by law enforcement (officers can only report what they are told) as well as lack of self-reporting of sleepiness/fatigue by drivers (would be self-incriminating); 2) incompleteness of crash data on direction of travel at time of crash (~30% completed) to adequately determine distance to rest area/truck stop straight ahead for all cases and controls (for this reason, U-turns were also included in the calculated distances); 3) availability of additional public and private truck parking that may not have been identified for inclusion in the analysis; 4) length of time driving by the commercial vehicle driver before the crash was unknown that could also have affected sleepiness/fatigue; 5) commercial vehicle driver medical conditions and medication use were unknown at the time of the crash; 6) possible sleepiness/fatigue human factor coding bias by law enforcement in injury-related crashes vs. non-injury related crashes and vs. coding of other human factors in at-fault commercial vehicle driver crashes since a higher percentage of the sleepiness/fatigue-related crashes were injury crashes; and 7) daily truck traffic volume for the interstates and parkways that may serve as a fatigue-protective factor was not included in the study since truck traffic volume at the specific case and control crash sites could not be determined.

Regarding possible underreporting of the fatigue and sleepiness variables, as well as of the other human factor variables such as distraction/inattention variables, the majority of nonfatal human factor crash variables are reported based on both the statement of the driver and the judgment of the reporting officer (personal communication, Kentucky State Police), so there could be self-report bias. Fatal commercial vehicle crashes are more likely to be fully investigated by a crash reconstructionist who is a police officer, and a final report is submitted based on the impressions of both the investigating police officer and the reconstructionist officer. According to a former Kentucky State Police crash reconstructionist, officers check evidence at the scene of a crash for braking, skid marks, steering, etc. If a crash is fatal and investigated by a reconstructionist, the driver's 24 h history is reviewed. Based on all these data, collision causation factors are recorded. A number of published studies have examined driver risk factors for crashes using sleepiness variables reported through crash data (Filtness et al., 2017a; Filtness et al., 2017b; Bunn et al., 2005; and Tefft, 2012). Tefft (2012) analysis of U.S. crash data from the National Highway Traffic Safety Administration National Automotive Sampling System's non-imputed data found that 3.9% of all passenger vehicle crashes involved a driver coded as drowsy; this percentage is similar to our results (284 at-fault commercial drivers with sleepiness/fatigue contributing to the collision out of 7538 at-fault commercial drivers with contributing human factor for the collision [3.98%]). Our study was focused on drivers of commercial trucks who were listed at fault with a cited human factor. Non-commercial truck drivers were not included. The results from this study cannot be generalized beyond collisions occurring in Kentucky due to the differences in the landscape, traffic intensity and character, and other factors defining the circumstances of the collisions that occur in the state. The results, however, can inform studies and efforts in other states and countries where long-haul commercial drivers may be prone to at-fault collisions due to lack of rest areas on the roads.

5. Conclusions

The use of statewide crash data analysis coupled with ArcGIS mapping capabilities provided the opportunity to both statistically determine and to visualize the association between rest area/weigh station with rest haven/truck stop distance and the occurrence of commercial vehicle driver at-fault crashes involving sleepiness/fatigue. This dual approach may be particularly useful for linked crash data sets such as trauma, emergency department, inpatient hospitalization, and mortality data to comprehensively evaluate the contribution of other factors for commercial vehicle driver crashes such as substance use (e.g., drugs on board vs. those administered at the site of the crash by emergency responders), distance to local trauma centers, rural/urban differences, and co-diagnosed medical conditions such as obstructive sleep apnea, and diabetes. Also, implementation and evaluation of commercial vehicle employer policies and interventions such as the use of commercial vehicle driver fatigue alert systems, and driving schedules that allow adequate time for breaks and minimize night time driving, may help to reduce fatigue and sleepiness-based crashes in commercial vehicle drivers. These results can be used by state and local highway transportation officials to inform and increase truck parking availability, especially on parkways. Discussions in the state have already been initiated to convert former rest areas into truck parking and to create new truck parking availability on interstates and parkways in Kentucky.

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