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Abstract

Introduction: Injuries and fatalities due to large truck and other vehicle crashes have decreased over the last decade, but motor vehicle injuries remain a leading cause of death for both the working and general populations. The present study was undertaken to determine semi truck driver and sleeper berth passenger injury risk in a moving semi truck collision using a matched-pair cohort study.

Method: Study data were obtained from the Kentucky Collision Report Analysis for Safer Highways (CRASH) electronic files for 2000 - 2010. A matched-pair cohort study was used to compare the odds of injury of both drivers and sleeper berth passengers within the same semi truck controlling for variables specific to the crash or the semi truck. The crude odds ratio of injury was estimated and a statistical model for a correlated outcome using generalized estimating equations was utilized.

Results: In a moving semi truck collision, the odds for an injury were increased by 2.25 times for both semi truck drivers and sleeper berth passengers who did not use occupant safety restraints compared to semi truck drivers and sleeper berth passengers who used occupant safety restraints at the time of the collision. The driver seat or sleeper berth position in the vehicle was not a significant factor (*p*-value= 0.31) associated with a moving semi truck collision injury. **Conclusion:** Nonuse of occupant safety restraints by either drivers or sleeper berth passengers significantly increased the odds of an injury in a moving semi truck collision; semi truck seating position (driver's seat or sleeper berth) did not increase the odds for an injury in moving collisions.

Impact on Industry: Trucking companies should include the mandatory use of occupant safety restraints by both semi truck drivers and sleeper berth passengers in their company safety policies.

Keywords: sleeper berth occupant safety restraints semi truck driver injury

Research Highlights:

- Motor vehicle injuries are a leading cause of worker death.
- The odds of injury in a moving semi truck collision significantly increased for those semi truck drivers and sleeper berth passengers who did not use an occupant safety restraint.
- The driver seat or sleeper berth position in the semi truck was not a significant factor in predicting injury in a moving semi truck collision injury.

1. Introduction

Although injuries and fatalities due to large truck and other vehicle crashes have decreased over the last ten years, motor vehicle injuries remain a leading cause of death in the US for both the working and general populations (Federal Motor Carrier Safety Administration [FMCSA], 2011; Centers for Disease Control and Prevention [CDC], 2007; National Institute for Occupational Safety and Health [NIOSH], 2011). In 2009, there were 2,179 fatal combination truck (defined as a truck tractor pulling any number of trailers, a bobtail truck tractor not pulling any trailers, or a straight truck pulling at least one trailer) crashes in the US with 340 combination truck occupant fatalities; 289 drivers of large trucks were killed (FMCSA, 2011)

Semi truck drivers have a grueling timetable and drive extended hours behind the wheel. Some companies employ team drivers so that delivery schedules can be adhered to while accounting for hours of service rules. In a survey of long distance truck drivers, approximately 19.5% of drivers from Oregon and 8.5% of drivers from Pennsylvania shared truck driving (McCartt *et al.* 2008). Passengers in the semi truck sleeper berth accounted for 11 fatalities in 2009, 19 fatalities in 2008, and 19 fatalities in 2007 (National Highway Traffic Safety Administration, 2011). Of the 49 sleeper berth passenger fatalities, 47 were not using an occupant safety restraint system and two victims had an unknown occupant safety restraint system use status.

The use of occupant safety restraints is associated with a decreased risk in injury severity in both passenger vehicle and commercial vehicle collisions (Cummins *et al.* 2008; Cummins *et al.* 2011; Bunn *et al.* 2005; Talmor *et al.* 2010). Restraint usage may be lower among semi truck drivers compared to passenger vehicle occupants (Kim and Tremblay, 2005). In 2011, observed occupant safety restraint usage was 84% for occupants in passenger cars (NHTSA, 2011). In a survey of commercial motor vehicle drivers, 74% were observed using an occupant safety restraint; the occupant safety restraint usage rate was 61% for other occupants in the commercial motor vehicle (FMCSA, 2009). Safety belt use among commercial vehicle drivers was higher in states with a primary seat belt law (78%). The use of occupant

safety restraints by both semi truck drivers and sleeper berth passengers may, therefore, be important components of trucking company worker safety policies.

Funded by the National Institute for Occupational Safety and Health, state Fatality Assessment and Control Evaluation (FACE) programs investigate worker deaths in order to develop reports that contain feasible, practical injury prevention recommendations for worker safety training use by employers and workers. The Kentucky FACE program has targeted semi truck driver and passenger deaths for investigation since the year 2005 because of the high number of worker fatalities in the transportation industry and in semi trucks, in particular. From 2005 to 2010, 119 semi truck drivers, and 13 semi truck passengers have died in collisions on Kentucky roadways (Kentucky Injury Prevention and Research Center). Of the 13 semi truck passengers who died, 2 were in the sleeper berth. Of the 132 total deaths, 20 fatality reports have been produced and disseminated to employers.

Due to the high number of semi truck driver and passenger fatalities in Kentucky, and the percentage of semi truck team drivers on the road, the present study was undertaken to determine if passengers in the sleeper berth were at a higher risk of injury in a semi truck collision compared to semi truck drivers using a matched-pair cohort study.

2. Method

2.1. Study Data

Data for the study were obtained from the Kentucky Collision Report Analysis for Safer Highways (CRASH) electronic files for 2000 - 2010 from the Kentucky State Police Records Section which contained all reported crashes on public roadways in Kentucky. The electronic file received contained all motor vehicle collision information but excluded some personal identifiers. This 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 Selection Criteria

Selection of the cases for the study was determined in the following order:

1. Semi truck with sleeper berth (identified by unit type= “21”, “22”, “23”, or “24” or National Crime Information Center [NCIC] type= “SE”)
2. Presence of passenger in sleeper berth at the time of collision (position in vehicle= “11[sleeper compartment]”)
3. Age of semi truck drivers $\geq$ 21 years of age and age of passengers $\geq$ 21 years of age
4. Moving semi truck collisions (Semi truck not in “parked” position at the time of collision)

Semi trucks with the pre-collision action recorded as “parked” were excluded from the analysis. The presence of the passenger in the sleeper berth was determined based on the “passenger position” variable. Using the selection criteria above, 708 semi trucks involved in collisions (containing both the driver and a passenger in the sleeper berth) were included in the final analysis.

2.3. Study Design and Analysis

A matched- pair cohort study was used to assess the association of occupant position and injury outcome in semi truck collisions. By matching drivers and sleeper berth passengers in the same semi truck, the effect of potential confounders specific to the crash or common for the occupants was controlled for. We used the odds ratio as a measure of the relationship between the injury outcome and the exposure variable (position in the vehicle). To further adjust the odds ratio for personal level confounders a statistical model for correlated binary outcomes using the method of generalized estimating equations (GEE) (Liang, Zeger, 1986) was utilized. The GEE are used previously in the analysis of motor vehicle crash data (Hutchings, 2003; Olsen, 2010). Our data have a clustered structure (each matched pair is a cluster) and observations from the same cluster (vehicle) tend to be more alike than observations from different clusters. The response variable modeled was *injured*, and coded as “1” when the police officer at the collision scene recorded that the occupant sustained fatal, incapacitating, or nonincapacitating injury, and coded as “0” otherwise (no injury or possible injury). The exposure variable of interest was the occupant position coded as “1” for an occupant in the sleeper berth at the time of the collision, and “0” for an occupant in the driver’s position. Age, gender, occupant safety restraint use, and vehicle area of first contact in the collision were considered potential confounders not involved in the

matching, and were included as explanatory variables in the statistical model. The analysis was performed with SAS® version 9.2, utilizing PROC GENMOD with binomial distribution and logit link function (Allison 1999, Stokes 2000). The GEE method was invoked by the REPEATED statement in PROC GENMOD where the SUBJECT was the vehicle number, identifying the matched driver-passenger pair. There was no multicollinearity issue with the explanatory variables (the variance inflation factors were below 3.3). Two-way interaction terms were included in the model but then dropped as none of the interaction terms were significant.

3. Results

3.1. Kentucky Semi Truck Collisions by Occupant Characteristics

Almost one-third of the semi truck drivers were between the ages of 35-44 years, and another one-third were between 21-34 years of age (Table 1). Passengers in the sleeper berth tended to be younger (35% who were 21-34 years of age compared to 29% who were 35-44 years of age). Semi truck drivers were older (14% who were 55 years old or older) compared to the percentage of sleeper berth passengers who were older (11% who were 55 years of age and older). A higher percentage of the semi truck drivers were male (84%) when compared to sleeper berth passengers (75%).

Almost all of the drivers were recorded as wearing occupant safety restraints by the police officer when the semi truck collision occurred (96%). In contrast, most of the semi truck sleeper berth passengers were recorded as not using their occupant safety restraint system at the time of the crash (85%) by the police officer. For 497 of the 708 matched pairs (70%), occupant safety restraint usage in the sleeper berth was coded by the police officer as “not installed” but we included that data in the analysis as “not restrained”. According to Federal Motor Carrier Safety Administration Regulation 393.76, Subpart G. Miscellaneous Parts and Accessories, “A motor vehicle manufactured on or after July 1, 1971, and equipped with a sleeper berth must be equipped with a means of preventing ejection of the occupant of the sleeper berth during deceleration of the vehicle. The restraint system must be designed, installed, and maintained to withstand a minimum total force of 6,000 pounds applied toward the front of the vehicle

and parallel to the longitudinal axis of the vehicle." The oldest vehicle in this study was from the 1980 model year, therefore, we assumed that all of the semi trucks in the present study had sleeper berth occupant safety restraint systems in place but that the police officer did not realize that a sleeper berth restraint system was standard equipment. The sleeper berth restraint system is typically tucked under the mattress (personal communication with three truckers) and is not visible to the police officer (personal communication with the Kentucky State Police).

Of the 708 semi truck collisions, there were four driver fatalities and nine sleeper berth passenger fatalities (Table 1). Of the nine sleeper berth passenger fatalities, only one was using an occupant safety restraint. Similar percentages of semi truck drivers and sleeper berth passengers were not injured in a moving semi truck collision (94% of the drivers [n=667] and 92% of the sleeper berth passengers [n= 652], respectively. Of the 41 injured semi truck drivers, 18 drivers received multiple injuries (2.5%), 15 received limb injuries (2.1%), 14 received neck/back injuries (2.0%), and 21 received other injuries (numbers may overlap). A higher number and percentage of sleeper berth passengers received serious injuries: 24 sleeper berth passengers received multiple injuries (3.4%), 24 received neck/back injuries (3.4%), and 22 received limb injuries (3.1%), most likely due to the nonuse of occupant safety restraints. Only two of the injured sleeper berth passengers were using an occupant safety restraint system. More semi truck sleeper berth passengers were ejected from the vehicle (n=7) or trapped (n=18) during the collision compared to the number of semi truck drivers who were ejected from the vehicle (n=4) or trapped (n=14) during the semi truck collision.

3.2. Kentucky Semi Truck Collisions by Collision Characteristics

Almost half of the semi truck collisions were angle/sideswipe crashes; one-third of the crashes were single vehicle crashes, and 19% were rear collisions (Table 2). Two-thirds of the semi truck crashes occurred in higher speed zones (55+ mph). Approximately one-fifth of all semi truck crashes were within lower speed zones of less than 35mph. Eight percent of the semi truck collisions resulted in overturns; twelve crashes resulted in a fire. When examining the first area of contact in the semi truck collisions, the front of the semi truck or the trailer were cited equally by the police officer as the first area of contact

(46% in the front and 46% in the trailer). Only about 9% of the semi truck collisions impacted the side of the semi truck (sleeper berth) first.

3.3. Kentucky Semi Truck Collision Driver-Passenger Pairs by Injury Status

As shown in Table 3, the semi truck driver and the sleeper berth passenger were both injured in 34 of the 708 semi truck collisions. In 91% of the semi truck collisions, neither the semi truck driver nor the semi truck sleeper berth passenger was injured. When only one occupant was injured in a moving semi truck collision, a higher percentage of sleeper berth passengers were injured than semi truck drivers; in 22 of the 708 semi truck collisions, only the semi truck sleeper berth passenger was injured (3.1%), and in seven of the 708 semi truck collisions, only the semi truck driver was injured (1.0%). The crude odds ratio for sleeper berth passengers vs. drivers to be injured was 1.40 with a 95% confidence interval from 1.10 to 1.79. After matching on the vehicle and controlling for vehicle- and collision-specific factors, the occupants in the sleeper berth were found to be at significantly higher odds for being injured in a moving vehicle collision compared with the occupants in the driver seat. This result, however, could be confounded by other occupant specific characteristics such as age, gender, and the use of occupant safety restraints. To adjust the odds ratio for these potential confounders we used a statistical model for correlated binary outcomes using the GEE method.

3.4. Kentucky Semi Truck Collision Regression Analysis for Matched-Pair Data

The results from the final statistical model for *injured* with GEE adjustment for matching are shown in Table 4. After adjusting for correlated outcome data and controlling for age, gender, occupant safety restraint use, and area of first contact, the position in the vehicle (driver or sleeper berth passenger) was not significantly associated (OR 0.72; 95% CI [0.38, 1.36]) with the injury outcome in a moving semi truck collision. Age (OR 1.00; 95% CI [0.99, 1.02]) and gender (OR 1.19; 95% CI [0.81, 1.73]) were also not significantly associated with the modeled outcome of injury. The use of an occupant safety restraint was a significant protective factor (OR 2.25; 95% CI [1.15, 4.41]) in reducing the risk of injury in a moving semi truck collision. The adjusted odds for a semi truck occupant to be injured who was not restrained at the time of the moving semi truck collision was 2.25 times the odds for a semi truck

occupant who was restrained at the time of the collision, while controlling for other factors. This means that the adjusted odds to be injured for a sleeper berth passenger who was not restrained at the time of the moving semi truck collision were significantly higher than for a sleeper berth passenger who was restrained at the time of the collision. Similarly, the adjusted odds for a not restrained semi truck driver to be injured were significantly higher than for a semi truck driver who was restrained at the time of the collision.

Not surprisingly, head-on moving semi truck collisions significantly increased the odds for occupant injuries compared with other areas of first contact on the semi truck. An occupant in a moving semi truck collision where the area of first contact was the front of the vehicle had 11.46 the odds of injury compared to an occupant in a moving semi truck collision where the first area of contact was the trailer (controlling for the other factors in the model). The odds ratio for injury when the initial contact was the sleeper berth area vs. the trailer was 4.59 with a 95% confidence interval = [1.19, 17.67].

The estimated correlation in the working correlation matrix was fairly high at 0.64. SAS v.9.2 provided observation-level and cluster-level diagnostics for models fit by GEE, based on formulas developed by Preisser and Qaqish, (1996). There were no observations or clusters with unusually large leverage or Cook's D values. The plots of standardized DFBETAs for each variable in the model were explored. There were four clusters that seemed to have a larger impact on the estimates but after investigating the observations in the clusters we concluded that the observations were plausible and retained them in the model.

4. Discussion

The results of this study show that semi truck drivers and sleeper berth passengers who were not using occupant safety restraints significantly increased the odds of injuries in moving collisions compared to those semi truck occupants who were using occupant safety restraints. The seating position in the semi truck (driver seat or sleeper berth) was not a significant factor associated with an injury in a moving truck collision. Also, age and gender did not influence injury outcome in a moving semi truck collision; the

only risk factors that increased the odds of an injury were nonusage of occupant safety restraints and the area of first contact in the collision (front or side [sleeper berth] of the semi truck).

Commercial vehicle carriers should implement and enforce a workplace policy that requires all vehicle occupants (including drivers, and sleeper berth passengers) to use occupant safety restraints while riding in a moving commercial vehicle. Federal laws require all drivers, including commercial vehicle drivers, to wear seat belts while operating a motor vehicle but no laws, to our knowledge, require the use of occupant safety restraints in the sleeper berth. In this study, almost all of the semi truck drivers were belted (96%) according to the CRASH report; in contrast, only 15% of sleeper berth passengers were coded as using an occupant safety restraint system at the time of the crash. The occupant safety restraint percentages may be overestimated for both drivers and sleeper berth passengers in nonfatal crashes: 1) occupant safety restraint use could have been self-reported to the police officer; and 2) drivers who are not using their occupant safety restraints in a moving vehicle are subject to a fine.

Sleeper berth occupant restraints have been required by the FMCSA as standard equipment installed in semi trucks since 1971. The results of this present study indicate that the use of sleeper berth occupant restraint systems is very low among sleeper berth passengers. An informal FACE program phone survey of 20 long-haul team drivers (convenience sample) indicated that the primary reason for non-usage of sleeper berth occupant restraint systems among long-haul team drivers was that the occupant restraint system encumbered sleep. Semi truck manufacturers should revisit the design of sleeper berth occupant protection systems so that the sleeper berth occupant is adequately restrained while the vehicle is in motion but movement is not severely restricted while the occupant is sleeping.

The results of this present study showed that the first area of contact (front or side) was associated with an increased risk of injury for semi truck drivers and sleeper berth passengers in a moving semi truck collision. The area of first contact (front or side of vehicle) on a passenger vehicle has been associated with injury severity among drivers (Conroy *et al.* 2008). Drivers of passenger vehicles in wide frontal impacts were 4 times more likely to have a serious head injury in head-on motor vehicle crashes. Increasing the frontal crash strength of semi truck cabs has been suggested to provide protection from

intrusion in approximately 66% of all frontal semi truck crashes (Krishnaswami and Blower, 2003). In addition, other characteristics of the crash (driver-, passenger-, vehicle-, and crash-) may influence injury severity in large truck crashes, (Zhu and Srinivasan, 2011).

There are a number of limitations of the present study. Electronic CRASH data does not contain narrative information to ascertain whether the passenger was a team truck driver. To reduce the possibility of non-team drivers in the sleeper berth, only those passengers 21 years of age were included in the study. Second, this study did not examine makes and models of the semi trucks involved in a moving collision in order to assess vehicle crush differences between vehicle types. Lastly, occupant safety restraint usage could have been self-reported in a non-fatal collision and, therefore, overestimated. The overestimation may be different between drivers and sleeper berth passengers since drivers are subject to a fine for not using their occupant safety restraints while driving.

5. Impact on Industry

Commercial vehicle carriers should implement and enforce a workplace policy that requires all vehicle occupants (drivers and sleeper berth passengers) to use occupant safety restraints while the semi truck is moving. To improve occupant restraint usage among sleeper berth passengers, commercial vehicle manufacturers should consider the redesign of sleeper berth occupant restraint systems to allow for adequate protection of the occupant in the event of a collision while not encumbering sleep.

6. Acknowledgements

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Table 1. Kentucky Semi Truck Collisions by Occupant Characteristics, 2000- 2010.

Occupant Characteristics	Drivers N (%)	Sleeper Berth Passengers N (%)
Age (years)		
21-34	220 (31.1)	246 (34.7)
35-44	224 (31.6)	202 (28.5)
45-54	162 (22.9)	182 (25.7)
55-64	84 (11.9)	67 (9.5)
65+	18 (2.5)	11 (1.6)
Gender		
Male	592 (83.6)	529 (74.7)
Female	116 (16.4)	168 (23.7)
Missing	0 (0)	11 (1.5)
Occupant Safety Restraint Use		
Used	682 (96.3)	101 (14.3)
Not Used	20 (2.8)	602 (85.0)
Missing	6 (0.8)	5 (0.7)
Injury Severity		
Fatal	4 (0.6)	9 (1.3)
Incapacitating	12 (1.7)	11 (1.5)
Non-incapacitating	25 (3.5)	36 (5.1)
Possible injury	27 (3.8)	34 (4.8)
None	640 (90.4)	618 (87.3)
Injury Location		
Head/Face	13 (1.8)	12 (1.7)
Neck/Back	14 (2.0)	24 (3.4)
Chest/Abdomen/Pelvis	8 (1.1)	8 (1.1)
Arms/Hands/Legs/ Feet	15 (2.1)	22 (3.1)
Multiple	18 (2.5)	24 (3.4)
Missing (indicates no injury or no possible injury)	640 (90.4)	618 (87.3)
Ejection from Vehicle		
Not ejected	701 (99.0)	695 (98.2)
Ejected	4 (0.6)	7 (1.0)
Missing	3 (0.4)	6 (0.8)
Trapped		
Not trapped	691 (97.6)	686 (96.9)
Trapped	14 (2.0)	18 (2.5)
Missing	3 (0.4)	4 (0.6)

Table 2. Kentucky Semi Truck Collisions by Collision Characteristics, 2000- 2010.

Collision Characteristics	N	(%)
Manner of Collision		
Angle/Sideswipe	349	(49.3)
Head-On	18	(2.5)
Turn-opposing, away, into	2	(0.3)
Rear end/Rear to rear/ Backing	133	(18.8)
Single vehicle	206	(29.1)
Posted Speed Limit (mph)		
<35	147	(20.8)
35-44	34	(4.8)
45-54	52	(7.3)
55+	475	(67.1)
Overturn		
No	648	(91.8)
Yes	58	(8.2)
Fire		
No	694	(98.3)
Yes	12	(1.7)
First Area of Contact		
Vehicle- front, right/left bumper	322	(45.5)
Sleeper berth- right, left	64	(9.0)
Trailer-front, back, rear, right, left, top/bottom, double trailer	322	(45.5)

Table 3. Kentucky Semi Truck Collision Driver-Passenger Pairs by Injury Status, 2000-2010.

	Driver		
Sleeper Berth Passenger	**Injured**	**Not Injured**	**Total**
Injured	34	22	56
Not Injured	7	645	652
Total	41	667	708

Table 4. Adjusted Odds Ratios for Injury, 2000-2010.

	Adjusted Odds Ratio Estimate	95% Confidence Limits
Sleeper berth passenger vs. driver	0.72	(0.38, 1.36)
Unrestrained vs. restrained	2.25	(1.15, 4.41)
Female vs. Male	1.19	(0.81, 1.73)
Age	1.00	(0.99, 1.02)
Area of first contact - Front vs. Trailer	11.46	(4.43, 29.68)
Area of first contact - Sleeper berth vs. Trailer	4.59	(1.19, 17.67)