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Analytical Observational Study of Nonfatal Motor Vehicle Collisions and Incidents in a Light-vehicle Sales and Service Fleet

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Abstract

Motor vehicle crashes (MVCs) are a significant cause of lost-workday injuries, and consistently the leading cause of work-related fatalities in the United States for all industries combined. Prevention research has focused mainly on collisions fatal to the drivers of large trucks. This analytical observational study addresses gaps in the literature by: conducting a descriptive analysis of motor vehicle claim events involving light-vehicle drivers in a large health care industry fleet; identifying risk factors for work-related MVCs and injuries based on vehicle miles traveled; and providing details on circumstances of these events.

The study included 8,068 motor vehicle events reported by 6,680 U.S.-based drivers in a light-vehicle sales and service fleet operated by a health care company over a 4 ½-year period (January 2010 through June 2014). The analysis included events which resulted in vehicle or property damage, or in injury. Motor vehicle claims data were merged with data on drivers, vehicles, and vehicle miles traveled. Collisions were segmented as recoverable or non-recoverable according to whether the company could recover costs from another party, and mileage-based collision and injury rates were calculated by gender, age, tenure, and vehicle type. Differences in collision and injury rates between groups of interest (for example, tenure and age categories) were assessed with Poisson regression techniques adjusted using generalized estimating equations (GEE) for repeated observations on the same employee over time (years).

Age, gender, and job tenure were significant collision risk factors, with similar risk patterns for recoverable and non-recoverable collisions. Nonfatal collisions per million miles (CPMM) were significantly higher for drivers less than 25 years of age compared to drivers age 25 to 54.9 years (9.58 CPMM vs 4.96 CPMM, p=.025), drivers employed for less than 2 years compared to those employed 2 or more years (6.22 CPMM vs 4.22 CPMM, p<.001), for female drivers compared to male drivers (6.37 CPMM vs 4.16 CPMM, p<.001), and for drivers of passenger cars compared to all other vehicles (5.27 CPMM vs 4.48 CPMM, p<.001). Among collision types with 10 or more injuries, collisions where the front of one vehicle hit another vehicle at an angle while turning left or moving straight ahead were the most likely to result in injury to the employee driver or

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another party, with 41.9% of angle collisions resulting in injury. Rear-end collisions accounted for the greatest number of injuries (n=294), but were less likely (31.6%) to result in injury than were angle collisions.

The findings suggest that in addition to trying to prevent non-recoverable collisions where the employee driver's actions contributed to the event (for example, through policies to reduce risks of distracted, fatigued, and impaired driving), employers should also provide strategies that will help employee drivers avoid being involved in collisions that result from the actions of another driver (for example, through training in defensive driving). Special attention should be given to preventing collisions among newly-hired employees, and to preventing angle and rear-end collisions, which were most likely to result in injury.

Keywords

Work-related motor vehicle crashes; Employee drivers; Fleet safety

1. Introduction

The risk of involvement in a work-related motor vehicle crash (MVC) as a driver or passenger affects millions of U.S. workers. MVCs occurring on or off a public roadway are consistently the leading cause of work-related fatalities for all industries combined. Of 66,588 work-related fatalities reported by the Census of Fatal Occupational Injuries (CFOI) between January 1, 2003 and December 31, 2015, 30% (n=19,648) were MVCs fatal to a driver or passenger (Bureau of Labor Statistics 2018a).[1] MVCs made up the majority of workplace fatalities for workers employed in transportation and material moving occupations, accounting for 57% of the total in 2015. They are also a leading cause of death for occupations where driving is not the primary job duty, for example, managers and sales workers (Bureau of Labor Statistics 2018b).

Nonfatal work-related MVCs also have substantial injury and economic consequences for workers and employers. In 2015, private-industry workers sustained an estimated 31,130 lost-workday injuries due to roadway incidents involving a motorized land vehicle and 6,930 lost-workday injuries due to non-roadway incidents (Bureau of Labor Statistics 2018c). For both roadway and non-roadway incidents, about 60% of these were serious enough to result in 6 or more lost workdays, and 33% of the total resulted in 31 or more lost workdays (Bureau of Labor Statistics 2018c). Further, the Liberty Mutual Workplace Safety Index estimated that serious roadway incidents involving motorized land vehicles accounted for $3.7 billion in workers' compensation costs in the U.S. in 2014 (Liberty Mutual Research Institute for Safety 2017). In 2013, a single on-the-job crash involving a nonfatal injury was

[1]As defined by the Bureau of Labor Statistics, work-related MVCs comprise three broad categories: (1) *Roadway incidents involving a motorized land vehicle* are "events involving transportation vehicles under normal operation, on roadways, which includes the parts of the public highway, street, or road normally used for travel, as well as the shoulder or surrounding areas, telephone poles, bridge abutments, trees aligning roadway, etc.;" (2) *Non-roadway incidents involving a motorized land vehicle* "closely mirror the coding scheme for roadway incidents, but include only those instances that occur entirely off of a public roadway, such as in a field, factory, or parking lot;" and (3) *Pedestrian vehicular incidents* include "pedestrians and other nonoccupants of vehicles who are struck by vehicles or other mobile equipment in normal operation regardless of location." Pedestrian incidents are outside the scope of this paper.

estimated to cost the employer almost $65,000 on average, regardless of liability (Network of Employers for Traffic Safety 2015).

The current study seeks to address three research gaps in the published literature on work-related MVCs: (1) the limited number of published analyses of nonfatal (as opposed to fatal) work-related MVCs; (2) the lack of research on crashes involving fleet drivers of light vehicles for whom, unlike truck drivers, driving is not the primary job duty but who nonetheless may have substantial exposure to crash risk; and (3) the lack of research on fatal or nonfatal work-related crashes involving light vehicles that assesses crash or injury risk based on actual driving exposure.

With regard to the first gap cited, the limited number of published analyses of nonfatal (as opposed to fatal) work-related MVCs, the primary national data source for nonfatal work-related injuries is the Survey of Occupational Injury and Illness (SOII), an annual survey of employers conducted by the Bureau of Labor Statistics. The SOII provides national estimates of the numbers of workers who sustain nonfatal injuries by industry, occupation, event, nature and source of injury, body part, and demographic characteristics. However, beyond describing an event in general terms (that is, as a roadway or non-roadway incident involving a motorized land vehicle, or a pedestrian struck by a motor vehicle), the SOII provides no antecedent or incident details that would help inform crash prevention activities.

With regard to the second gap noted, the vast majority of U.S. literature on work-related MVCs addresses known and hypothesized risk factors for truck drivers, including driver fatigue and hours of service [see, for example, (McCartt et al. 2000, Pack et al. 2006, Blanco et al. 2011, Jovanis et al. 2011, Lemke et al. 2016, Marcus and Rosekind 2017)]; medical conditions [see, for example, (Hartenbaum et al. 2006, Orris et al. 2007, Wiegand et al. 2009, Smolensky et al. 2011, Sieber et al. 2014, Birdsey et al. 2015, Thiese et al. 2015)], and use of mobile devices [see, for example, (Olson et al. 2009, Hickman and Hanowski 2012, Swedler et al. 2015)]. Few U.S. studies have been published on MVCs in non-truck driving occupations, and most of these do not examine specific risk factors for crashes. Non-truck driving populations that have been studied are law enforcement officers (Bean and Noh 2010, Tiesman et al. 2013), workers operating agricultural equipment on public roadways (Costello et al. 2009, Gkritza et al. 2010), construction workers (Ore and Fosbroke 1997), emergency medical services workers (CDC 2003), workers in the mining sector (Janicak 2011), and oil and gas extraction workers (Retzer et al. 2013, Bell et al. 2017).

The third gap addressed by this study is the lack of research that adequately estimates crash risk for workers driving light vehicles using exposure data such as vehicle miles traveled (VMT) or hours of driving (Robertson 1998). Previous descriptive analyses, whether based on fatal or nonfatal injury data, have relied on number of persons employed (or number of full-time equivalent employees) to calculate injury or fatality rates (Driscoll et al. 2005, Pratt and Rodríguez-Acosta 2013, Retzer et al. 2013, Chen et al. 2014). This approach does not account for the substantial differences in exposure to motor vehicle traffic across occupations and industries. The study reported here addresses this gap by using monthly mileage data linked to the driver and the vehicle to calculate incident and injury rates.

For workers whose primary job is not driving, but who use passenger vehicles for sales calls or other client contacts such as service calls, on-the-job use of motor vehicles is largely unregulated by the U.S. federal government. Parameters for managing work-related road safety are set by state traffic laws, voluntary consensus standards (ANSI/ASSE 2017) and industry-specific guidelines (International Association of Oil & Gas Producers 2016), and policies and procedures put in place by employers. Empirical data are needed to help organizations direct crash-prevention efforts toward the types of incidents that are most likely to result in injury, liability, and substantial damages to vehicles and other property. The objective of this study reported here was to address that need by conducting a descriptive analysis of motor vehicle claims events involving drivers in a large sales and service fleet operated by a health care company, identifying risk factors for work-related MVCs and resulting injuries and providing details on the circumstances and risk factors for these events.

2. Methods

2.1 Study design

This was an analytical observational study whereby collisions and risk factors were studied as they occurred in the workplace without manipulation by researchers. Motor vehicle collisions, including trends over time, and differences between driver sub-groups were quantified and analyzed, taking into account potential confounders.

2.2 Study population

The study population came from a collaborating company that provides health care products and services. The focus of this research was all the company's sales and service employees in the United States (from all 50 states plus the District of Columbia) who drive thousands of miles each year as part of their job selling products and servicing medical devices at customer locations. To be eligible for inclusion in the study, drivers had to have been a current employee as of June 30, 2014, and drivers also must have concurred with a company privacy policy that allowed the company the use of their demographic information and driving history for research purposes. Approximately 97% of eligible drivers concurred. For the eligible drivers, data records for January 1, 2010 through June 30, 2014 were obtained retrospectively. If eligible drivers were hired after January 1, 2010, data records were obtained from their hire date through June 30, 2014. Therefore, drivers contributed for different lengths of time, which affected the number of miles each driver contributed to the data.

Sales drivers for the collaborating company choose from a range of passenger vehicles (primarily cars, "crossovers,"[2] and minivans) leased for their individual use by the company. Service drivers use company-provided vehicles for travel to client locations for servicing of medical devices. In addition to being used for business purposes, company-provided

[2]A crossover is a vehicle that has the larger size and practicality of a sport utility vehicle (SUV), but its ease of handling and fuel efficiency are more like that of a car. A crossover has a "unibody" construction where the body and frame are a single piece, while an SUV is assembled from a separate body and frame.

vehicles are also available for personal use and eligible and authorized family use (employee's spouse or domestic partner only).

2.3 Ethics

This study was approved by the Institutional Review Board of the U.S. Centers for Disease Control and Prevention's National Institute for Occupational Safety and Health (NIOSH). All records used in this study came from pre-existing databases collected and maintained by the collaborating company and its fleet safety partners for administrative purposes. To minimize the risk of loss of privacy, each driver in the study was assigned a unique, anonymous driver ID. The driver ID was created and held only by authorized personnel from the collaborating company, and never shared with NIOSH. This unique, anonymous driver ID was used in each of the data sets described in Section 2.5, Data sources.

2.4 Outcome measure

The outcome measure used in this study was collisions while the driver's vehicle was "in transport,"[3] which includes the driver's vehicle being stopped in traffic or at a traffic sign or signal. Collisions in transport included those with other motor vehicles in transport, pedestrians, animals, and fixed and non-fixed objects (for example, parked cars, telephone poles, debris in the roadway, tree limbs). Collisions both on and off the roadway were included. Off-roadway incidents included collisions in parking lots or work sites. The collisions used for the outcome measure were identified through the company's motor vehicle claims database, as described in Section 2.5, Data sources. Incidents other than those used as the outcome measure (for example, non-collision events such as damage while parked and windshield damage only) were summarized descriptively but no rates were calculated and no statistical tests were performed.

2.5 Data sources

2.5.1 Vehicle and mileage data—Data on driving exposure were obtained from records that tracked the vehicle assigned to each employee each month, and how many miles were driven on that vehicle each month. Vehicle mileage for a given month was based on the last odometer reading for the month as shown on fuel receipts, minus the last odometer reading for the previous month. As the vehicles were used for both business and personal travel, it was not possible to distinguish between miles driven for each purpose; thus, they are combined in this study.

If drivers changed vehicles over the course of the study, this information was captured in the data. Vehicles were coded as passenger cars or other vehicles – in this fleet, primarily "crossovers" and minivans – per the classification scheme used by the National Highway Traffic Safety Administration (NHTSA) to code cases in the Fatality Analysis Reporting System (National Highway Traffic Safety Administration 2016).

[3]The term "in transport" denotes that the motor vehicle was in operation on a roadway or in motion within or outside the trafficway. Vehicles that are stopped at a traffic sign or signal are still considered to be in transport.

2.5.2 Demographic data—A driver's hire date and birth date were used to create values for job tenure and age. The data set included the employee's gender. No data were available on employee race or ethnicity. Age and tenure categories were chosen based on both comparability to categories used in previously published motor vehicle literature, as well as to minimize any cells with sparse or missing data for a multivariate analysis (categories defined in Section 2.6, Data analysis).

2.5.3 Motor vehicle claims data—The company's motor vehicle claims database was used to identify the outcome measure, collisions. This database contained any event (no exclusions) reported by an employee driver to the company's crash management center which resulted in vehicle or property damage, a first report of injury, or any combination of these. Although vehicles could be used for both business and personal travel by the employee driver and for personal travel by the employee's family members, only claims where the employee was the driver were used in this analysis.

For each event, the motor vehicle claims data did not provide a determination of "fault" per se, thus a *Recoverability* variable present in the data for each event was used as a proxy. An event was coded as "recoverable" or "non-recoverable" according to whether or not there was a basis for the collaborating company to recover costs from another party. It is, however, important to note that "non-recoverable" events generally fell into one of two groups: those in which the employee driver's actions overtly contributed (for example, a collision with another vehicle where the employee driver disregarded a traffic signal); and those in which there was no other party involved (for example, vehicle damage from an act of nature). Determination of injury to either the employee driver or another party was based on the employee driver's report to the company's crash management center.

2.5.4 Supplemental text mining/data extraction and coding of motor vehicle claims data—To increase comparability to standard coding systems for MVCs, motor vehicle claims data were reviewed and manually re-coded by the NIOSH research team based on event types found in the Model Minimum Uniform Crash Criteria (MMUCC) 4th edition, a national guideline designed to generate uniform crash data for data-driven highway safety decisions within and between states and at the national level (U.S. Department of Transportation 2012).

Events that involved a motor vehicle in transport were assigned to a *Main Type* equivalent to the MMUCC main categories for *First Harmful Event*: Non-collision; Collision with person, motor vehicle, or non-fixed object; and Collision with fixed object. Within these *Main Types*, each event was further categorized into a *Sub-type* based on the MMUCC categories found under each *First Harmful Event*. Although MMUCC is designed to be used for coding incidents which occur in traffic on public roadways, it was found to be suitable for coding similar events in the data set which occurred off public roadways.

One group of incidents present in the collaborating company's data set fell outside the scope of MMUCC: non-collisions where the motor vehicle was not in transport. The original MMUCC coding scheme does not cover incidents involving damage to a parked and unattended vehicle. To address this, the study team added a fourth *Main Type*, "Non-collision, vehicle not in transport," and added relevant *Sub-types* within this *Main Type*, for example, struck by other vehicle while parked, weather damage, or vandalism.

For events that occurred while the company vehicle was in transport, the MMUCC variable *Motor Vehicle Maneuver/Action* was also coded. This variable denotes the intended direction of travel at the beginning of the sequence of crash events, for example, straight ahead, turning left, backing, or changing lanes. Because the study data were derived from employee drivers' reports to the crash management center, it was only possible to code *Motor Vehicle Maneuver/Action* for the company's vehicle. For events involving a collision between two or more vehicles in transport, an additional MMUCC variable, *Manner of Collision/Impact*, was coded. This denotes the orientation of the two vehicles as they initially came together, for example, front to rear, angle, or sideswipe. *Manner of Collision/Impact* was coded from the perspective of the company's vehicle, for example, a collision in which their vehicle struck the rear of another vehicle was coded as "front to rear."

2.6 Data analysis

All datasets were merged by the unique, anonymous driver ID number. The unit of analysis was driver-month, with both collisions and total miles driven available at the monthly level. Based on previous MVC research findings, four potential risk factors present in the collaborating company's administrative databases were examined: age, gender, job tenure, and vehicle type. Age, gender, and job tenure were found in previous studies to be risk factors for, or associated with, work-related MVCs and fatality rates (Janicak 2003, Driscoll et al. 2005, Tiesman et al. 2010, Pratt and Rodríguez-Acosta 2013, Retzer et al. 2013, Chen et al. 2014). Vehicle type was also examined as a risk factor (CDC 2011, Retzer et al. 2013, Byler et al. 2016).

SAS v. 9.3 software (SAS Institute 2013) was used for management and statistical analysis of study data. Poisson regression (using PROC GENMOD) was used to analyze the data, where a count of number of collisions was related to monthly vehicle mileage as an exposure measure. Generalized estimating equations, using the REPEATED statement and an exchangeable correlation structure, were used in the Poisson regression models to account for potential within-driver correlation (repeated monthly measurements on the same driver over time) (Liang 1986, SAS Institute 2013, Huang et al. 2016). Demographic variables of age, gender, and tenure, and vehicle body type were each tested separately in a univariate Poisson regression analysis, then the three demographic variables were entered together in a multivariate model to test for significant covariation among the variables. Age was treated as a three-level variable with values of age <25 years, age 25 years to 54.9 years, and age ≥ 55 years, gender was a dichotomous variable with values of male or female, and tenure was a dichotomous variable with values of <2 years since hire date or ≥ 2 years since hire date. Vehicle body type was a dichotomous variable with values of passenger car or all other types.

The one exception to the use of Poisson regression for significance testing was that repeated measures analysis of variance (ANOVA), using PROC MIXED, was used to do a post-hoc test for differences in mean monthly mileage among age groups and between genders, with mileage used as a continuous variable. Repeated measures ANOVA was used to account for repeated measures of total miles driven per month for each driver in the study.

3. Results

3.1 CPMM by year, driver demographics, and vehicle type

There were 6,680 unique drivers in the data set who drove 24,411 miles a year on average. For the 4 ½-year study period, the overall rate of collisions per million miles (CPMM) was 5.04, and the rates of non-recoverable and recoverable collisions were 2.87 and 2.17, respectively (Figure 1 and Table 1). The rate of total CPMMs increased significantly over the course of the study (rate ratio=1.06 per year, $p<.001$).

Of the 6,680 drivers, 3,850 (57.6%) were male. In comparison to males (4.16 CPMM), females had significantly higher rates (6.37 CPMM) in the univariate test ($p<.001$), as well as in the multivariate test ($p<.001$) (Table 1). To supplement collision rates, monthly driving patterns were examined by gender. Male drivers drove an average of 2,163 miles per month, and female drivers drove 1,868 miles, which was significantly fewer miles per month on average than males (Table 2).

Drivers younger than age 25 had the highest collision rates, with drivers aged 25 to 54.9 years and 55 years or older having significantly lower rates in the univariate test ($p<.001$ and $p=.011$, respectively). In the multivariate analysis, drivers aged 25 to 54.9 years had significantly lower collision rates compared to drivers younger than age 25, but drivers 55 years or older were no longer significantly different from drivers under 25 years (Table 1). To supplement collision rates, monthly patterns of driving were examined for drivers in each age category. Drivers younger than age 25 drove an average of 1,888 miles per month, below the overall fleet average of 2,034 miles per month, and drivers younger than age 25 drove significantly fewer miles per month on average than did drivers in the older age categories (Table 2).

Among tenure categories, drivers with less than 2 years tenure with the company had significantly higher CPMMs compared to drivers with 2 or more years tenure (6.22 vs 4.82, $p<.001$ for both the univariate and multivariate test) (Table 1).

Passenger cars, which accounted for 74.6% of total miles driven, had a significantly higher rate (5.27 CPMM) in comparison to all other vehicles combined (4.48 CPMM) (Table 1).

3.2 Motor vehicle claims: collisions vs non-collisions

The claims data set contained 8,068 events (including one event for which an event type could not be coded) and 464 reported injuries (5.8% of all events), 295 of which were to the collaborating company's driver (3.7% of all events) (Table 3). The majority of events were non-collisions (n=5,407, 67.0%), very few of which resulted in injury. Collisions with a person, motor vehicle, or non-fixed object (n=2,222, 27.5%) accounted for 440 of the 464 total reported injuries (94.8%) and 282 of the 295 injuries to the employee driver (95.6%). Among collisions, those with another motor vehicle in transport had the highest likelihood of injury among all event types; 25.3% resulted in any injury, and 16.4% resulted in injury to the employee driver.

3.2.1 Collisions with injuries—
Among collision types resulting in 10 or more injuries, two dominated: rear-end collisions, and angle collisions where the company's vehicle was either turning left or moving essentially straight ahead (Table 4). Together, these accounted for 17.3% of collisions resulting in an injury.

Rear-end collisions accounted for 35.0% of total collisions (930 of 2,660, Table 3). Rear-end collisions were also the collision type that resulted in the greatest number of injuries: 294, or 65.5% of all injuries (n=449) that were due to a collision with another motor vehicle in transport.

Although much less frequent than rear-end collisions, angle collisions where the employee driver's vehicle was turning left or moving essentially straight ahead had greater likelihood of any injury or injury to the employee driver, with 41.9% resulting in any injury, and 27.0% resulting in injury to the employee driver.

3.3 Recoverability

Total collisions were separated by recoverability status and examined descriptively, but were not tested for significance. With regard to demographic factors, patterns seen in recoverable and non-recoverable collisions separately were similar to those for total collisions. That is, both recoverable and non-recoverable collisions showed an increasing trend over the course of the study (Figure 1) and had the same risk factor patterns, with highest rates for drivers under 25 years of age, drivers with less than 2 years of job tenure, and for female drivers (Table 1).

Among collisions involving the company vehicle and another motor vehicle in transport, recoverable collisions were far more likely than non-recoverable collisions to result in any injury (30.1% compared to 6.3%) or in injury to the employee driver (20.4% compared to 3.6%) (Table 4). With regard to type of collision, rear-end and angle collisions were the most likely to result in injuries, regardless of recoverability (Table 4). One area where a difference was noted by recoverability was the likelihood of injury given a rear-end collision. When an employee driver rear-ended another party (non-recoverable) the percentage of collisions with any injury was lower (14.7%) than when other another party rear-ended the employee driver (recoverable) (40.2%).

4. Discussion

This large study of sales and service drivers employed by a health care company adds to the literature by beginning to fill the substantial gap in analyses of nonfatal MVCs among fleet drivers of light vehicles for whom driving is not their primary job duty. Collision rates were calculated by gender, age, job tenure, and vehicle type, as well as according to whether costs were deemed to be recoverable through another party's insurance. One of the key findings was that age, gender, and tenure were significant collision risk factors, and that risk patterns were similar for recoverable and non-recoverable collisions.

Unlike most other studies to date, this study also calculated collision rates using monthly VMT as the measure of driving exposure, with mileage data linked to the company vehicle provided to each employee driver. The use of VMT as the exposure measure led to results that differ from earlier studies of work-related crashes that used number of workers as the measure of exposure. For example, the findings from this study are inconsistent with crash data by gender for the general population, where males have higher rates of involvement in all types of MVCs: 3 times the rate of involvement in fatal crashes, 1.3 times the rate of involvement in injury crashes, and 1.4 times the rate of involvement in property-damage-only crashes (National Highway Traffic Safety Administration 2017). These crash involvement rates by gender for the general population are calculated per 100,000 licensed drivers instead of the more precise VMT data available for this study.

The finding that females had significantly higher collision rates than males is also inconsistent with a number of other studies of work-related crashes, which reported significantly higher likelihood of fatality or serious injury for males (Driscoll et al. 2005, Sultana et al. 2007, Boufous and Williamson 2009, Tiesman et al. 2010, Pratt and Rodríguez-Acosta 2013). However, these studies vary in their scope and methodology, limiting direct comparison to our results. First, some studies focused only on MVC fatalities (Driscoll et al. 2005, Tiesman et al. 2010, Pratt and Rodríguez-Acosta 2013), whereas our study examined nonfatal MVCs. Second, another of these studies did focus on nonfatal MVCs, but reported rates of crash-related injuries paid by workers' compensation (Sultana et al. 2007), not overall collision rates as were reported in our study. Third, some studies included all workers in the denominators used to calculate rates, regardless of exposure to traffic hazards at work (Driscoll et al. 2005, Tiesman et al. 2010, Pratt and Rodríguez-Acosta 2013, Retzer et al. 2013). Fourth, our study population drove in a sales-and-service workplace driving environment that does not represent the manufacturing industry as a whole.

The findings from this study also differ from other studies of fatal work-related MVCs by age, which report the lowest rates among the youngest workers and the highest rates among the oldest workers (Janicak 2003, Driscoll et al. 2005, Tiesman et al. 2010, Pratt and Rodríguez-Acosta 2013, Chen et al. 2014). Most of these studies included only fatal MVCS and used employment-based denominators (that is, denominators based on the total number of workers rather than exposure to traffic hazards) (Janicak 2003, Driscoll et al. 2005, Tiesman et al. 2010, Pratt and Rodríguez-Acosta 2013, Chen et al. 2014), limiting comparability to our results. Another study, based on workers' compensation claims, reported MVC injury rates using the number of workers as the measure of exposure. This study found wide variation in injury rates by age, with the lowest rates among workers age 65 or older, and rates for the youngest workers comparable to the rate for workers of all ages (Sultana et al. 2007).

The primary reason for the discrepancy between our findings and the existing literature is likely our use of VMT data as the measure of exposure. An employment-based denominator assumes equal driving exposure across all segments of the workforce, which may not actually be the case. A review of denominator choices for crash rates for the general population noted the difficulty of placing individuals in a denominator if they have varying levels of exposure or no exposure at all (Morris 2015). The use of employment-based denominators for calculating work-related MVC rates exemplifies this deficiency. VMT, used in our study for rate calculation, is a more precise exposure measure than number of workers or numbers of vehicles in a company fleet.

In this study, the analysis of average monthly VMT by age demonstrated that drivers who were under age 25 drove significantly fewer miles compared to all other age groups, and that female drivers drove significantly fewer miles than males. This study did not collect information on factors related to driving distance. However, factors that could potentially affect driving distance are age and gender differences in territory size, familiarity with routes, rural vs. urban territories, workload, or occupation.

Patterns of collision rates by job tenure were similar to those by age, with drivers employed for less than 2 years with the collaborating company having significantly higher collision rates than drivers employed for longer periods. These findings are consistent with a study of workers in the oil and gas extraction industry who died in work-related MVCs (Retzer et al. 2013). In this study, of the 60% of fatalities for whom tenure was reported, 52% had less than 1 year tenure and another 20% had 1 to 3 years tenure. These findings support the value of crash-prevention efforts targeted to the newest employee drivers. Further, these findings suggest practical actions for employers because they can be applied equally, regardless of employees' age, race, or gender.

Collision rates for passenger cars were significantly higher than for all other vehicle types. The data set for this study had no information on the type of vehicle(s) that struck or were struck by the employee driver's vehicle, so it was not possible to assess the implications of differences in vehicle type or size for individual collisions. The findings for total collisions are consistent with crash involvement rates for the general population, which are higher for passenger cars than for light trucks (a category where national data include both utility vehicles and vans). Based on VMT, in 2015 passenger cars were 1.4 times as likely as light trucks to be involved in an injury-producing crash, and 1.3 times as likely to be involved in a property-damage-only crash (National Highway Traffic Safety Administration 2017).

Risk patterns by demographic factors were similar for both recoverable and non-recoverable collisions. It is possible that companies may place greater emphasis on prevention of non-recoverable collisions because these would be associated with higher direct costs and potential liability in cases of third-party involvement. In this study, 81% of collisions were non-recoverable, and 76% of these were collisions with another motor vehicle in transport, a parked vehicle, or a fixed object. In these cases, future collisions may be avoided through interventions such as company policies to mitigate distracted, fatigued, and impaired driving; driver training; and checking motor vehicle records regularly to ensure that the employee is maintaining a safe driving record on and off the job (Pratt and Rodríguez-Acosta 2015, ANSI/ASSE 2017).

Further examination of recoverable collisions is warranted because these were found to be much more likely to result in injury to the employee driver than were similar non-recoverable events. Data available for this study did not provide demographic information about the other parties responsible for recoverable collisions; however, a better understanding of recoverable collisions will offer employers the opportunity to avoid similar events in the future or reduce their severity. For example, training in defensive driving is intended not only to prevent crashes that may result from the trainee's actions; it is also intended to teach that individual how to avoid being involved in a crash due to the actions of other motorists (Lund and Williams 1985). For both recoverable and non-recoverable collisions, employer policies requiring the use of seat belts in all seating positions can help reduce the severity of crashes that do occur (National Highway Traffic Safety Administration 1984, Kahane 2015).

This study identified the types of collisions most often associated with injury to the employee driver or another person. High proportions of angle collisions (with the company vehicle moving straight ahead or turning left) resulted in injury to the employee driver or another person. Analyses of these crashes for the general population show that angle collisions are associated with high likelihood of severe injury or fatality, particularly side-impact crashes with contact between vehicles at the 3 o'clock or 9 o'clock positions (that is, at a right angle) (Laberge-Nadeau et al. 2008). Further, an in-depth analysis of intersection-related crashes reported that for 60% of crashes, the critical event was a left-turn error (Choi 2010). Based on these findings, companies should consider advising employees to avoid left turns when possible, incorporating this into routing practices for drivers with regular routes.

Although rear-end collisions accounted for greater numbers of injuries than any other collision type, they were less likely than angle collisions to result in injury. However, unlike angle collisions, which had similar proportions of injury-producing collisions regardless of recoverability, recoverable rear-end collisions were more than 4 times as likely to result in injury as non-recoverable rear-end collisions. This difference may be attributed to vehicle position in the collision. By definition, a recoverable rear-end collision would have been one in which the company vehicle was struck by the vehicle behind it, and in these types of collisions it is the occupant of the leading vehicle who is more severely injured (Khattak 2001).

To prevent angle and rear-end collisions, which were the most likely to result in injury, employers could consider offering training to help drivers recognize precursors to these crash scenarios and apply preventive strategies. They may also consider selecting vehicles with safety features such as forward collision warning with automatic emergency braking and lane-departure warning.

This research has several limitations. First, it is not known how generalizable these findings are to other driver populations. However, although the analysis focused on one specific fleet, due to that fleet's large size and national distribution, the results may be applicable to many classes of drivers of light vehicles. Further, these fleet drivers worked in different driving environments; some used the vehicle for sales calls across a wide geographic area, others for service calls, and others only for short trips to local clients or the airport.

The use of first report of injury, generally by the employee, as the proxy for injury is another limitation; some initial reports of injury may have been incorrect, and in other cases an injury may have become apparent only after the first report. The lack of data on nature of injury or injury severity is another limitation. Cost data were not incorporated into this study, as the data available to researchers were limited to vehicle repair or replacement costs associated with the company's vehicle, with no information on medical or liability costs.

In addition, event data were coded from the perspective of the employee driver only. Self-report of risk factors by the employee driver may have omitted certain behavioral risk factors that might have been identified in a police investigation, for example, driver fatigue or mobile phone use. However, each collision was assessed as to recoverability, that is, whether or not costs for a claim could be recovered from another involved party because the other party's actions caused the loss. The data set reflects a final determination of recoverability; therefore, we can be confident about the contribution of the employee driver's actions or another party's actions to the incident.

Further, mileage in this study was based on driving done for business and personal use by the employee, but it may also have included mileage logged for personal travel by an employee's spouse or domestic partner. We were unable to separate miles driven per month by driver (employee vs. spouse) or trip purpose. Although the collaborating company manages and is responsible for all claims from the vehicle (regardless of whether an employee or spouse was driving), only claims incurred while the employee was driving were used in this analysis. Therefore, the denominator might be slightly inflated for assessment of employee risk, thus making rates presented in this paper an underestimate by an unknown degree.

5. Conclusions

This study led to development of a complex data set for a large corporate fleet using inputs from multiple administrative sources. The result was a detailed observational analysis of nonfatal work-related motor vehicle events, rare in the peer-reviewed literature. To enhance compatibility of the current study findings with national crash data, event data were coded using the coding scheme recommended for police crash reports, and vehicle types were coded using NHTSA coding schemes.

This research addressed gaps in the literature by examining risk for non-fatal work-related collisions, whereas most previous research has focused on fatal MVCs. In addition, it used light-vehicle fleet drivers as the study population, a group of occupational drivers not widely addressed by other studies. Finally, this study calculated collision risk based on vehicle mileage, which is preferable to using exposure measures based on the number of employees. The findings suggest a need for future research to further explore crash risk for female light-vehicle drivers, and both younger and newer employee drivers. In addition, the findings on collisions between vehicles confirm the need to continue to apply recognized strategies to prevent these events. Particular attention should be given to prevention of angle and rear-end collisions, which in our study were associated with high numbers and likelihood of injury. Training and vehicle selection policies may help to prevent these types of collisions.

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Highlights

- Motor vehicle claims data were merged with driver and vehicle data for a light-vehicle sales and service fleet.
- Mileage-based collision rates were higher for females, drivers less than age 25, and employees with less than 2 years tenure.
- Risk did not differ substantially by whether or not collision costs were recoverable through another party's insurance.
- Angle and rear-end collisions were most likely to injure the employee driver or another party.
- Collision prevention should focus on new employees, and both recoverable and non-recoverable collisions.

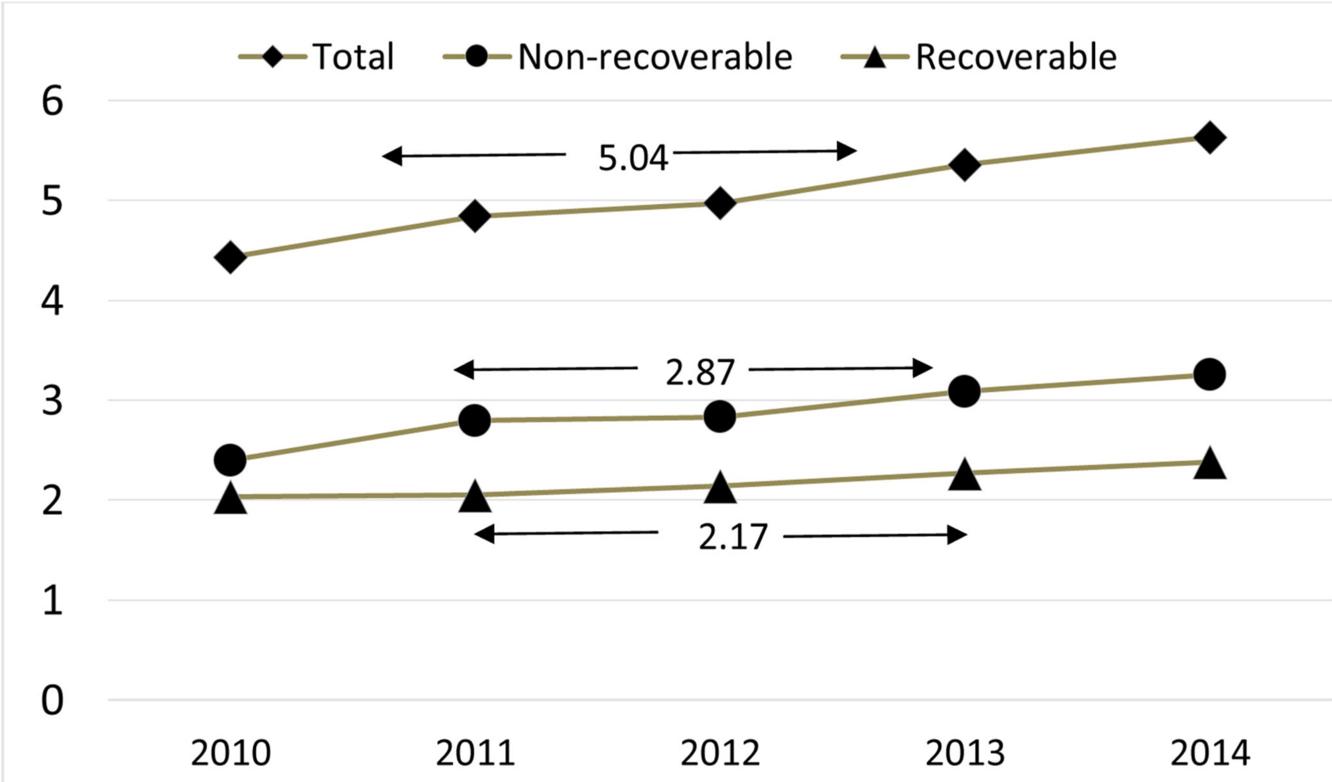

Figure 1. Collision rates per million miles, 2010–2014, total and by recoverability.
Note: 2014 rate is for January-June.

Table 1.

Collision frequencies and rates by recoverability and driver and vehicle characteristics.

		Collisions			Collisions per million miles			
	Drivers [1]	Total # collisions	# Non-recoverable	# Recoverable	Total collisions [2]	p-value [3]	Non-recoverable collisions	Recoverable collisions
Total	6,680	2,660	1,515	1,145	5.04		2.87	2.17
Gender [4]								
Male	3,850	1,315	745	570	4.16	----	2.36	1.80
Female	2,830	1,345	770	575	**6.37***	**<.001***	3.65	2.72
Age (years) [4]								
<25	162	34	19	15	9.58	----	5.35	4.23
25–54.9	6,268	2,421	1,386	1,035	**4.96***	**0.025***	2.84	2.12
≥55	250	205	110	95	5.73	0.207	3.08	2.66
Tenure (years) [4,5]								
<2	2,824	527	305	222	6.22	----	3.60	2.62
≥2	3,856	2,133	1,210	923	**4.82***	**<.001***	2.73	2.08
Vehicle body type [2,6]								
Passenger car	----	1,981	1,112	869	5.27	----	2.96	2.31
Other (mostly "crossover" and minivans)	----	679	403	276	**4.48***	**<.001***	2.66	1.82

[1] For counts, drivers were assigned to demographic categories based on the earliest month they appeared in the dataset. No drivers had missing values for any of the variables used in the analysis.

[2] Values with asterisk and bold font denote significant differences between rate compared to rate for reference group, for bivariate relationship with CPMM only.

[3] P-values were generated from a multivariate Poisson regression analysis with gender, age, and tenure together in the model. Significant differences between rate compared to rate for reference group are shown with asterisk and bold font. P-values from univariate tests are in the body of the paper. There was no evidence found for a significant within-driver correlation as the exchangeable working correlation matrix value was <.01.

[4] The first category presented under each group heading (Gender, Age, Tenure, Vehicle) is the baseline category to which all other categories in that group were compared in significance tests using Poisson regression analysis.

[5] The rate for tenure <1 year was 6.73 CPMM and tenure 1-<2 years was 5.77.

[6] Vehicle body type was tested in a univariate Poisson regression analysis, separate from the multivariate analysis of demographic variables.

Table 2.

Average monthly vehicle mileage by age group and gender.

Age (years)[1]	Average monthly mileage	p-value[2]	Gender[3]	Average monthly mileage	p-value[2]
<25	1,888.1	---	Male	2162.6	---
25–54.9	2037.6	**<.001**	Female	1868.3	**<.0001**
≥55	2,004.7	**<.001**			

[1]Age <25 years is the baseline category to which all other age categories were compared in significance tests.

[2]Significant differences between average monthly mileage of each group compared to baseline group. Repeated measures analysis of variance was used to test for differences between group means.

[3]Male is the baseline category to which female was compared in significance tests.

Table 3.

Key outcome variables by event type.

Main/sub event type	Events	Injuries	Injuries to employee driver	% events with any injury	% events with employee driver injury
All event types	**8,067**[†]	**464**	**295**	**5.8**	**3.7**
Non-collision, Vehicle not in transport[†]	**3,023 (37.5%)**	**10**	**3**	**0.3**	**0.1**
Other	1,029	0	0	0.0	0.0
Windshield damage	805	0	0	0.0	0.0
Vandalism	329	0	0	0.0	0.0
Struck by other vehicle while parked	522	9	3	1.7	0.6
Weather	172	0	0	0.0	0.0
Non-collision, Vehicle in transport	**2,384 (29.6%)**	**5**	**4**	**0.2**	**0.2**
Thrown, falling, flying object	2,058	1	1	0.0	0.0
Collision with person, motor vehicle, or non-fixed object	**2,222 (27.5%)**	**440**	**282**	**19.8**	**12.7**
Collision with another motor vehicle in transport	1,686	427	276	25.3	16.4
Collision with animal (live)	178	4	4	2.2	2.2
Collision with other non-fixed object	162	1	1	0.6	0.6
Collision with parked motor vehicle	153	0	0	0	0
Collision with fixed object	**438 (5.4%)**	**9**	**6**	**2.1**	**1.3**
Other fixed object	113	1	1	0.9	0.9
Other type of post, pole or support	100	0	0	0	0

[†]Table excludes 1 event for which event type could not be coded.

Table 4.

Key outcome variables by detailed collision type[¥] and recoverability for collision events with 10 or more injuries (recoverable and non-recoverable combined).

Main/sub event type	Collisions	Injuries	Injuries to employee driver	% events with any injury	% events with employee driver injury
Total					
Collisions with motor vehicle in transport[†]	**2,660**	**449**	**288**	**17.3**	**10.8**
Rear-end collision: Collision with motor vehicle in transport / Front-to-rear collision with company vehicle moving essentially straight ahead, slowing, or stopped in traffic	930	294	190	31.6	20.4
Collision with motor vehicle in transport / Turning left, or moving essentially straight ahead / Angle	148	62	40	41.9	27.0
All other collisions with motor vehicle in transport[†]	1,582	93	58	5.9	3.7
Non-recoverable					
Total non-recoverable collisions with motor vehicle in transport[†]	**1,515**	**95**	**54**	**6.3**	**3.6**
Rear-end collision: Collision with motor vehicle in transport / Front-to-rear collision with company vehicle moving essentially straight ahead, slowing, or stopped in traffic	293	43	19	14.7	6.5
Collision with motor vehicle in transport / Turning left, or moving essentially straight ahead / Angle	51	23	15	45.1	29.4
All other non-recoverable collisions with motor vehicle in transport[†]	1,171	29	20	2.5	1.7
Recoverable					
Total recoverable collisions with motor vehicle in transport[†]	**1,145**	**354**	**234**	**30.1**	**20.4**
Rear-end collision: Collision with motor vehicle in transport / Front-to-rear collision with company vehicle moving essentially straight ahead, slowing, or stopped in traffic	637	251	171	39.4	26.9
Collision with motor vehicle in transport / Turning left, or moving essentially straight ahead / Angle	97	39	25	40.2	25.8
All other recoverable collisions with motor vehicle in transport[†]	411	64	38	15.6	9.4

[¥] Combines main event type, sub-type, motor vehicle maneuver/action, and manner of collision.

[†] Among cases included in this row, no combination of main event type, sub-type, motor vehicle maneuver/action, and manner of collision resulted in 10 or more injuries.