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Investigation of Differences between Male and Female Young Drivers Using Injury Severity Models

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ABSTRACT

Problem: Gender differences of young drivers involved in crashes and the associated differences in risk factors have not been fully explored in the United States (U.S.). Accordingly, this study investigated the topic, where the Odds Ratios (OR) were used to identify differences in crash involvements between male and female young drivers.

Method: Logistic regression models for injury severity of young male drivers and young female drivers were also developed. Different driver, environmental, vehicle, and road related factors that have affected young female drivers' and young male drivers' crash involvement were identified using the models.

Results: Results indicated that some variables are significantly related to female drivers' injury risk but not male drivers' injury risk and vice versa.Variables such as driving with valid licenses, driving on weekends, avoidance or slow maneuvers at time of crash, non-collision and overturn crashes and collision with a pedestrian were significant variables in female driver injury severity model but not in young male driver severity model. Travel on unleveled roadways, travel on concrete surfaces, travel on wet road surfaces, collision with another vehicle, rear-end collisions were variables that were significant in male driver severity model but not in female driver severity model.

Summary: Factors which increase young female drivers' injury severity and young male drivers' injury severity were identified. Some factors are significantly related to female drivers' injury risk but not male drivers' injury risk and vice versa. This study adds detailed information about gender differences and similarities in injury severity risk of young drivers.

Keywords: gender, young drivers, driving safety issues, severity modeling, crash data analysis

INTRODUCTION

In 1970, ratio of licensed male drivers to licensed female drivers in the U.S. was 13:10 (USDOT, 2011). In 2005, the number of female drivers exceeded the number of male drivers for the first time in U.S. According to 2011 driver license data, over 50.4% of U.S. drivers were females (USDOT, 2013).Females and males have some differences in driving that affect their attitudes and safety. According to the literature, males take more risk on the road, commit more driving violations, receive more traffic citations, and involve in more motor vehicle crashes than females (Butters et al., 2012). The basis for these differences may be because neurochemical structure of humans, hormonal process, global socialization practices, and many others. However, studies based on crash data report that older females are over represented in crashes compared to males (Classen et al., 2012). The causes for this over representation are errors of yielding, and gap acceptances.

Many studies identified the gender differences of young drivers in crashes but the main objective of those studies were not the investigation of the gender differences. Also, number of studies have focused on the relationship between gender and crash risk but those studies have not consistently investigated gender differences related to different driver, environmental, road, vehicle, and crash factors. Some variables can be significantly related to female drivers' injury risk but not male drivers' injury risk and vice versa. The advantage of investigating all these factors separately is that it allows researchers to account for many injury severity factors for female and male drivers. Separate injury severity models for females and males provide better and in depth information about gender differences on injury severity risks (Obeng, 2011).

Accordingly, the objectives of this study was to identify the gender differences in crash risk and factors that contribute to it by developing separate injury severity models for female and male young drivers.

LITERATURE REVIEW

The gender differences of young drivers and crash risk have been previously explored. Nyberg and Gregersen (2007) investigated gender differences among age 18-24 year drivers in Sweden regarding practicing as learners, outcome of driving tests, crash involvement of first year of licensure. Data were obtained from crash statistics, license tests and questionnaire surveys from 611 females and 524 males. The survey data consisted with background variables, general questions on driving, lay instructions, and behind-the-wheels lessons at a driving school. The gender differences were tested using a Chi-Square statistic, an independent samples t-test, or the Odds Ratio (OR). Results showed that both 18-24 year old male and female student drivers practices driving approximately same amount of time. However, females begin their driving later during the learners period, more often perform lay-supervise driving for the specific purpose of training, practices more skills in different environment, receive a longer proportion of their driving instructions of their driving tuition from professional instructors compared to males. According to national statistics data, females were better on the written tests but not on the road tests. About 68.3% of crashes involving drivers during their first year of licensed driving were males. Males were involved in 1.9 more injury crashes per 1,000 licensed drivers than female drivers during the first year of licensed driving. The authors commented that driver education should focus not only on amount of time spending on training but also the importance of the content of learning process.

Based on the questionnaire survey conducted at the Middle East Technical University in Ankara, the causes of differences in driving between young men and women were investigated by Ozkan and Lajunen (2006). Total of 131 male and 86 female young Turkish drivers were participated in the survey. The analysis techniques such as reliability analysis, Pearson produce-moment correlations, and descriptive statistics were used for primary data analysis while Poisson, negative binomial, and hierarchical regression analyses were used to find the effect of gender variables on crashes. Results showed that gender predicted the number of total, active, passive crashes. Being a female was negatively related with the total, active and passive crashes and perceptual-motor skills were positively related to safety skills.

Zhang et al. (2011) investigated potential gender and age differences in traffic rule violation convictions and crashes subsequent to Driver Improvement Programs (DIP). Data collected during a DIP program during 2006-2008 were obtained from Iowa Motor Vehicle Division. Data records of 12,354 drivers were analysis in this study in order to examine the effect of factors such as driver specific information, DIP outcome, DIP location, and interaction effect among these factors on occurrence of subsequent convictions. The developed binary logit model showed conviction occurrence within 12 months after DIP. Statistical significant differences in the likelihood of conviction and crash occurrence were observed by driver gender, age, and conviction history. A higher percentage of male drivers and younger drivers had their first conviction and crash occurrence within the first 135 days after DIP. Male drivers who were in DIP program had a 16.3% lower probability of incurring convictions than other male drivers. Female drivers who completed DIP had a 17.5% lower probability of being involving in conviction than female drivers did not complete.

Obeng (2011) investigated gender differences in crash risk severities using geometric- and traffic-related, and crash data for signalized intersections. Geometric- and traffic-related data were obtained from technical drawings and site visits to majority of intersections with spotlight in Greensboro, North Carolina excluding the highway exit ramps. Crash data were obtained from the State crash database. Ordered logit models were developed for males and females to understand their injury severity risk. Results showed that driver condition, type of crash, type of vehicle driven, and vehicle safety features have different effects on females' and males' injury severity risk. Age and vehicle crashworthiness data were not included in this study. Hence, results for this study may diverge from results obtained from national aggregate data.

Bingham and Ehsani (2012) examined the relationship between younger driver's gender and crash type. Fatal data from Fatality Analysis Reporting System (FARS) and non-fatal data from General Estimation System were used to identify the commonly occurring crash configurations and determine young male and female driver over represented crash configurations. Crash configurations were obtained by combining point of impact, manner of collision, and vehicle role. Logistic regression analysis was used calculate relative Odds Ratios in order to compare four groups; male and female 15-19-year-old drivers, and male and female 45-64-year-old drivers. Results showed that younger male drivers were more likely to involve in signal-vehicle, and fatal head-on crashes while female drivers were more likely to involve in left- and right-hand crashes. Younger female drivers were more likely to involve fatal rear-end crashes compared to younger male drivers. Younger female drivers were about twice as likely to involve in leftside crashes compared to younger male drivers. Authors recommend further research on contributory causes for different crash configurations.

DATA

Crash data from 2007 to 2011 were obtained from Kansas Accident Reporting System (KARS) database, which is comprised of all police-reported crashes that have occurred in Kansas. The police officers fill an accident report form including contributory causes and send to KDOT within ten days of the investigation for any crash which occurs on a public roadway and which results in death or injury to any person or total property damage of $1,000 or more.More details of the recording of each of the variables can be found from the KDOT accident reporting manual (KDOT, 2012).Motor vehicle crashes involving young drivers were taken into account in this study excluding motorcycle and motor scooter crashes.In this study, drivers' age from 15 to 24 years were considered as young drivers.The KARS database from 2007 to 2011 contained 138,388 (30% of total crashes) young-driver-involved crashes. The KARS database consists of more than hundred driver, vehicle, accident, occupant factors, and contributory causes describing crashes. There were up to 10 contributing factors recorded in the traffic crash database for some crashes, while contributory factors were not recorded at all in some other crashes. In order to calculate the crash rates, driver's license information for each year by age was obtained from the U.S. Department of Transportation (USDOT, 2013)

METHOD

A logistic regression model was developed to identify variables expected to have an explanatory effect on injury severity of crashes involving drivers. Using the coefficient of the explanatory variables, risk factors which increase driver injury severity could be determined. The dependent variable, injury severity, has several discrete categories. The dichotomous nature of the dependent variable facilitates the application of logistic analysis, for which the probability of fatal injury against other injury-severitycategories is estimated by the maximum likelihood method (Long, 1997). When injury severity, the dependent variable, is ordered, it is much easier to interpret. The ordered logistic regression model is also known as the cumulative logistic model or oridinal logistic regression model. In the ordered logistic regression model, the dependent variable can be defined as set of categories as shown in Table 1. Hence, each estimated coefficient gives the probability of being in the set of categories on the left versus the set of categories on the right.

The probability of driver n being injured with severity outcome i is:

$$\Pi(x)_{ni} = P(U_{ni} \geq U_{ni'}), \quad \forall' \in I, \quad i' \neq i, \tag{1}$$

where:

$\Pi(x)$: the probability of x injury category

n: a driver

i: the injury severity of n driver (eg: fatal injury, incapacitating injury, minor injury, no injury)

U_{ni} : a function determining injury severity outcome i of the n driver

$U_{ni'}$: a function determining injury severity outcome i' of the n driver, and

I : a set of I possible, mutually exclusive severity categories

The logistic regression analysis assumes a driver-injury severity function has a linear-in-parameters form as:

$$U_{ni} = \beta_i x_n + \varepsilon_{ni} \tag{2}$$

where:

β_i : a vector of estimable coefficients for injury severity i and x_i is a vector of variables for driver n

ε_{ni} : a random component which has identically and independently distributed error terms

Then the logistic regression model is defined as follows (Long, 1997):

$$\Pi(x)_{ni} = \frac{e^{\beta_i x_n}}{\sum_{\forall i' \in I} e^{\beta_{i'} x_n}} \tag{3}$$

The maximum likelihood method is then used to estimate the coefficients.

In some cases, logistic regression results may seem paradoxical, which means the model fits the data well, even though none of the independent variables has a statistically significant impact on predicting the dependent variable. This could happened due to the correlation of two or more independent variables. The model may not be accurate if both correlated variables were included or removed from the model. This is because the independent variables are collinear and the results show multicollinearity. In traffic safety analysis, the goal is to understand how various independent variables impact the dependent variable; hence, multicollinearity is a considerable problem. One problem is that even though the variable is important, model results show that it is not significant. The second problem is that confidence intervals on the model coefficients will be very wide. To help assess multicollinearity, the correlation matrix of the independent variables was investigated. If the element of correlation matrix has high value, model fit is affected by multicollinearity of the independent variable correspondent to that element. Also, each independent variable can be predicted from other independent variables. The model-fit statistic such as individual R^2 value and a variance inflation factor (VIF) are high for any of the independent variables, and model fit is affected by multicollinearity. In such cases, only one of those two variables was used for the development of the model.

Odds Ratios

To measure the association between young male drivers' and young female drivers' characteristics, Odds-Ratios (ORs) and 95% Confidence Intervals (CIs) were calculated using binary logit analysis (Long, 1997). The OR is a widely used statistic in traffic safety studies for comparing whether the probability of a certain event is the same for two groups. The "odds" of an event (y) is defined as the probability of the outcome event occurring $(y = 1 / x_1, x_2, ..., x_p)$ divided by the probability of the event not occurring (Long, 1997).

$$Odds = \frac{P(y = 1 / x_1, x_2, ..., x_p)}{P(y = 0 / x_1, x_2, ..., x_p)} \quad (4)$$

The ratio of odds of one variable ($odds_1$) and odds of other variable ($odds_0$):

$$odds\ ratio = \frac{odds_1}{odds_0} \quad (5)$$

is called Odds Ratio (OR). It gives the relative amount by which the odds a variable ($odds_1$) increase (OR > 1.0) or decrease (OR < 1.0) when the value of one of the predictor variables ($odds_0$) is increased by 1.0 unit.

RESULTS AND DISCUSSION

The total number of young females involved in crashes during the five year period (64,430) was lower than the total number of males involved in crashes during the same period (73,958). Crash rates per 1,000 licensed drivers were higher for young male drivers (86.5) than young-female drivers (77.4).Differences between young male and female drivers in terms of crash rates confirmed the fact that males are at more risk than females. Frequencies, percentages, and crash rates related to each crash characteristic and contributory-causes-related variables for male and female young drivers were investigated. Descriptive data such as numbers of crashes, percentages and crash rates for each characteristic and contributory causes were presented in tabular format. The percentages were calculated per all drivers involved in crashes for the particular age group. Information such as "unknown" and/or "other" for some of variables was not presented in the tables, making the sum of the percentages not equal to 100. ORs were also used to investigate the relative crash involvement of young female drivers compared to young male drivers. Calculated OR values for driver-related characteristics are shown in Table 2.

Approximately 30.5% of young female drivers had restrictions on their driver licenses at the time of crash.A majority of young drivers involved in crashes held valid driver licenses. About 4.0% of young female drivers and about 5.7% of young male drivers were not wearing seat belts at the time of the crash.Approximately 5.9% of young male drivers were under the influence of alcohol at the time of the crash.When interpreting results, ORs greater than one showed greater association from the particular factor for young female drivers than young male drivers. For example, OR value 1.28 for restricted licensed means female drivers were 1.28 times the odds more likely to be involved in crashes when driving with restricted licenses than male drivers. According to OR values with 95% of CI, when evaluating female versus male drivers, it was clearly shown that male drivers were overrepresented in crashes when driving with invalid licenses, without restrained, and alcohol impaired compared to male drivers.

Table 3 shows the frequency, percentages, and ORs for environmental-related characteristics. About 24.7% of young-female-driver-involved crashes and 31.8% of young-male-driver involved crashes occurred in dark conditions. Young female drivers' crash rates per 1,000 licensed drivers were slightly higher for time between 9:00am and 5:00 pm than young male drivers and for all other environmental factors, young male drivers crash rates were higher. According the ORs, young females were overrepresented crashes when driving in daylight condition and driving in normal weather conditions compared to male drivers. Also, young female drivers were more likely to be involved in crashes on urban roads, and week days compared to young male drivers.

Frequencies, percentages, and ORs for road-related characteristics were shown in Table 4. Young male drivers had slightly higher crash percentages (10.4%) in off-roadway crashes than young female drivers while young female drivers had higher crash involvement (42.9%) at intersections than young male drivers. According to OR values, young female drivers were more likely to be involved in crashes on dry roads, black-tops or concrete surfaces, and straight and level roads compared to young male drivers. ORs further showed young female drivers were more likely to be involved in intersection-related crashes but less likely to be involved in off-roadway crashes compared to young male drivers. The calculated ORs shows there were not statistically significant crash involvement differences between young male versus female drivers that when traveling on wet road surfaces or with posted speed limits lower than 30 mph. Young male drivers were more likely to involved in crashes when they were traveling on roadways with posted speed limits higher than 60 mph.

Young female drivers had higher crash percentages when they were driving automobiles (76.5%) than young male drivers (58.9%) as shown in Table 5. About 16.9% of young males were involved in crashes when they were driving vehicles which were 15 years or older, while only 9.1% of young female drivers were involved in crashes when driving that age of vehicle.Young male drivers' crash rates per 1,000 licensed drivers were higher for all road related characteristics than young male drivers. According to OR values, young female drivers overrepresented in crashes when they were operating an automobile, compared to young male drivers. Young female drivers were more likely to be involved in crashes when they were operating a vehicle older than nine years compared to young male drivers.

There were 82 young female drivers and 216 young male drivers killed on Kansas roadways over five year time as shown in Table 6. About 1.1% of young drivers, out of all crashes involving young drivers, suffered disabled injuries. Young female driver percentage in injury crashes were (6.9%) slightly higher than male driver percentage in injury crashes (6.1%). A higher percentage of vehicles were destroyed at the time of young male drivers' crashes compared to those of female drivers. The percentage of young female drivers in crashes was (59.8%) slightly lower when they were driving on straight roadways, compared to young male drivers (61.3%). Young female drivers also had a lower crash-involvement percentage in collisions with a fixed object than young male drivers. Young female drivers had a higher crash-involvement percentage in rear end collisions and angle side impact collisions than male drivers.

According to the ORs of crash-related characteristics, young female drivers were more likely to be involved in an injury or possible injury crash compared to male drivers. Also, young male drivers were more likely to be ejected at the time of the crash, compared to female drivers. Compared with young male drivers, female drivers' vehicles were more likely to have minor damage or functional at the time of crash. According to the ORs, young female drivers showed higher crash involvement when they were attempting to stop, park, or back than male drivers. Young female drivers were a more vulnerable group for collision with another vehicle. Young male drivers were more likely to involve in head on collision compared to female drivers.

Contributory causes for young driver crashes were also investigated using Kansas crash data. Many factors might have combined to produce circumstances that led to a traffic crash, i.e. there was rarely a single cause of such an event. Driver-related contributory causes involve actions taken by, or the condition of the driver of the vehicle. Contributory causes for young female and male drivers are provided in Table 7. The contributory causes were reported according to the opinion of the investigating officer. Inattention (20.8%) was the top-ranked driver contributory cause in young female driver crashes followed by driving too fast (15.6%), failure to yield right-of-way (9.2%), and disregarding traffic sign/signals (4.5%). Those same driver-related contributory causes were also the most critical factors among young male drivers. ORs were also used to investigate relative crash involvement when comparing female drivers to male drivers. When interpreting results, ORs greater than one showed greater contribution from a particular factor for female drivers than male drivers. None of driver contributory causes was statistically significant at 95% of confidence interval indicating the faults among males and females were similar. As one can expect the environmental contributory causes were similar for both female and male drivers.

The developed injury severity models for crashes involving young female and male drivers, including model fit statistics, is shown in Table 8. The statistical significance of individual coefficients was tested using the Wald Chi-Square statistic. Variables such as driver seat belt use, air bag deployment, alcohol involvement, travel on rural roads, involve in run-off-road crashes, travel on debris-filled road surfaces, posted speed limit, vehicle age, driver ejection, vehicle damage, drive on straight roadway, and collision with an animal were significant at the 0.05 level in both models. The sign of the coefficient in all these variables in the female model were similar to male model.

Holding a valid license, driving during weekends, crash avoidance, attempting to stop or back, involving non collision overturn crashes, collision with a pedestrian, involving head on crashes were variables which were significant in female model but not in male model. Travel on unleveled roadways, travel with passengers, travel on concrete surfaces, travel on wet road surfaces, collision with a vehicle, rear end collision were the variables which were significant in male model but not in the female model.The test of the intercept merely suggests whether an intercept should be included in the model. Interpretation of the intercept in a logistic regression model depends on how the independent variables were defined. The intercept represents the logit of the probability of injury, if all of the characteristics are set to zero; consequently, the value of the intercept cannot be meaningfully interpreted. Negative coefficient estimates show the reduced probability of potential injury severity, while positive coefficient estimates show the increased probability of potential injury severity.

Variable 'seat belt use' in female model has a p-value less than 0.000 and a likelihood ratio of -1.045. That means, if the female driver is belted, the injury severity is less. Seat belt-restrained young male drivers were less likely to suffer severe injuries when involved in crashes. Effectiveness of seat belt restraint in reducing crash injuries is well known. The positive coefficient of the airbag deployed variable indicates that young drivers were more likely to suffer severe injuries when they were involved in crashes regardless of their gender. This is not an expected result because generally air bags are used to reduce injury severity when involved in crashes. It may be because air bags only activate for serious head-on crashes but not for minor crashes. Alcohol involvement was a significant factor which increased young driver injury severity. Alcohol increases the probability of severe injuries among young drivers.Increased injury severities could be expected when driving on rural roads, because of higher speeds and limited enforcement in rural areas. According to the developed models, young drivers were more likely to suffer severe crashes when driving on rural roads. The estimated coefficient for off-roadway crashes had a positive sign as expected. This means that young drivers' injury severity was higher when they were involved in run-off-the-road crashes. Young drivers were less likely to suffer severe injuries when involved in crashes on road surfaces with debris. This may be because they may drive with proper precaution on road surfaces with debris. The posted-speed-limit of roadways was also a significant factor in which lower speed decreased young drivers' injury severity. Driving on higher-posted-speed-limit roadway increased young drivers' injury severity as expected. Driving old vehicles, which may not have proper protective devices, contributed to greater severity. Young drivers in older vehicles were more likely to suffer severe injuries when involved in crashes. Youth driving newer vehicles were less likely to suffer severe injuries as expected. Conditions of ejection, and trapped at the time of crash, increased injury severity. Vehicle damage was a significant factor in which vehicle is destroyed; the probability of having a more severe injury will increase.

Young female drivers were less likely to suffer severe injuries when involving crashes while driving with valid licenses, or during weekends. They were more likely to suffer severe injuries in crashes occurring when the maneuver at the time of the crash was on a straight following road, attempting avoidance/ evasive of a crash, or stopping or backing. Also, involvement of non-collision and overturn crashes showed a higher injury severity for young female drivers. Collisions with pedestrians or animal showed decreased injury severity for female young driver. Head-on collisions and angle collisions showed increased injury severity for female drivers as expected. Young male drivers were more likely to suffer severe injuries in crashes occurring when the maneuver at the time of the crash was on a straight following road and less likely to suffer severe injuries for animal related crashes. Crashes on concrete surfaces, crashes on wet road surfaces, involve in rear end collisions, and collisions when backing up showed decreased injury severity for young male drivers. Young male drivers were more likely involve in severe injury crashes when travelling on unleveled roadways.

SUMMARY AND CONCLUSIONS

This study investigated the gender differences between crashes involving young female drivers versus young male drivers, using Kansas crash data. A detailed frequency analysis was carried out by calculating crash rates and ORs. Further, separate injury severity models were developed for young females and males. Factors which increase young female drivers' injury severity and young male drivers' injury severity were identified. Some variables are significantly related to female drivers' injury risk but not male drivers' injury risk and vice versa. Variables such as driving with valid licenses, driving on weekends, avoidance or slow maneuvers at time of crash, non-collision and overturn crashes and collision with a pedestrian were significant variables in female driver injury severity model but not in male driver model. Travel with passengers, travel on unleveled roadways, travel on concrete surfaces, travel on wet road surfaces, collision with a vehicle, rear-end collisions were variables that were significant in male driver injury severity model but not in female driver injury severity model. Many complex factors influence and contribute to both young female and male driving behaviors. The risk for these drivers has been attributed to failure to give time and attention, falling asleep, failure to yield right of way, driving too fast for conditions, following too closely, or distraction. This study adds detailed information about gender differences and similarities in injury severity risk to the transportation safety literature.

IMPACT ON INDUSTRY

It is important to note that the findings of this study show that gender differences do exists among young drivers. This sends a message to the industry that the transportation professionals and researchers are planning countermeasures to increase the traffic safety, they may need to focus on male and female drivers separately.

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Table 1 Definition of Dependent Variable in an Ordered Logistic Regression Model

Equation	Pooled categories	Comparison	Pooled categories
Equation 1	Fatal/disable injury	Compared to	Not-incapacitating/possible/No injury
Equation 2	Fatal/disable/ Not incapacitating injury	Compared to	Possible/No injury
Equation 3	Fatal/disable/ Not incapacitating/Possible injury	Compared to	No injury

Table 2 Driver-Related Characteristics

Driver-Related Characteristics	Young Female Drivers			Young Male Drivers			Young Female versus Young Male Drivers		
	Num.	%	Crashes per 1,000 drivers	Num.	%	Crashes per 1,000 drivers	**ORs**	95% CI Lower	95% CI Upper
Restriction Compliance									
Restricted license	19,662	30.5	23.64	18,858	20.5	22.06	**1.28**	1.25	1.31
No restrictions on driver license	41,354	64.2	49.73	49,045	66.8	57.37	**0.89**	0.87	0.91
License Compliance									
Valid licensed	60,264	93.5	72.47	66,536	89	77.83	**1.61**	1.55	1.68
Not licensed	3,419	5.3	4.11	6,302	8.5	7.37	**0.6**	0.57	0.63
Safety Equipment used									
Safety belt used	59,365	92.1	71.39	64,797	87.6	75.79	**1.66**	1.60	1.72
Safety belt not used	2,313	4.0	2.78	4,224	5.7	4.94	**0.62**	0.58	0.65
Airbag									
Airbag deployed	3,428	5.3	4.12	3,624	4.9	4.24	**1.09**	1.04	1.14
Airbag not deployed	58,990	91.6	70.94	66,606	90.1	77.91	**1.2**	1.15	1.24
Alcohol Flag									
No alcohol	63,155	98.0	75.95	69,616	94.1	81.43	**3.09**	2.90	3.3
Alcohol impaired driving	1,275	2.0	1.53	4,342	5.9	5.08	**0.32**	0.30	0.34

Table 3 Environmental-Related Characteristics

Environmental-Related Characteristics	Young Female Drivers			Young Male Drivers			Young Female versus Young Male Drivers		
	Num.	%	Crashes per 1,000 drivers	Num.	%	Crashes per 1,000 drivers	**ORs**	95% CI Lower	95% CI Upper
Light Conditions									
Daylight	48,355	75.1	58.15	50,234	67.9	58.76	**1.42**	1.39	1.45
Dark	15,941	24.7	19.17	23,536	31.8	27.53	**0.7**	0.69	0.72
Weather Conditions									
Normal conditions	53,102	82.4	63.86	60,429	81.7	70.68	**1.05**	1.02	1.08
Adverse conditions	11,103	17.2	13.35	13,249	17.9	15.50	**0.95**	0.92	0.98
Functional Class									
Rural roads	15,135	23.5	18.20	20,926	28.3	24.48	**0.78**	0.76	0.80
Urban roads	49,147	76.3	59.10	52,855	71.5	61.82	**1.29**	1.25	1.32
Construction/Maintenance Zone									
Work zone	1,647	2.6	1.98	1,769	2.4	2.07	**1.07**	1.00	1.15
No work zone	62,445	96.9	75.09	71,788	97.1	83.97	**0.95**	0.89	1.01
Time of Crash									
5.00-9.00-Morning	8,229	12.8	9.90	9,206	12.5	10.77	**1.03**	0.99	1.06
9.00-13.00-Noon	10,590	16.4	12.73	10,671	14.4	12.48	**1.17**	1.13	1.2
13.00-17.00-Afternoon	20,465	27.7	24.61	20,145	31.3	23.56	**1.19**	1.16	1.22
17.00-21.00-Evening	16,241	25.4	19.53	18,156	24.6	21.24	**1.04**	1.01	1.06
21.00-5.00-Night	9,225	14.3	11.09	15,460	20.9	18.08	**0.63**	0.61	0.65
Day of Week									
Week days	50,098	77.8	60.25	54,495	73.7	63.74	**1.25**	1.22	1.28
Week end	14,325	22.2	17.23	19,450	26.3	22.75	**0.8**	0.78	0.82

Table 4 Road-Related Characteristics

Road-Related Characteristic	Young Female Drivers			Young Male Drivers			Young Female versus Young Male Drivers		
	Num.	%	Crashes per 1,000 drivers	Num.	%	Crashes per 1,000 drivers	**ORs**	95% CI Lower	95% CI Upper
Crash Location									
On roadway	31,934	49.7	38.40	37,357	50.8	43.70	**0.96**	0.94	0.98
Intersection	27,651	42.9	33.25	28,776	38.9	33.66	**1.18**	1.15	1.20
Off roadway	4,796	7.4	5.77	7,719	10.4	9.03	**0.69**	0.66	0.72
Road Surface Type									
Concrete	17,819	27.7	21.43	19,424	26.3	22.72	**1.07**	1.05	1.10
Black top	42,921	66.6	51.61	48,189	65.2	56.37	**1.07**	1.04	1.09
Gravel/brick or other	3,480	5.4	4.18	6,104	8.3	7.14	**0.63**	0.61	0.66
Road Surface Condition									
Dry	49,221	76.4	59.19	55,533	75.1	64.96	**1.07**	1.05	1.10
Wet	8,978	13.9	10.80	10,453	14.1	12.23	**0.98**	0.95	1.01
Debris	5,902	9.2	7.10	7,583	10.2	8.87	**0.88**	0.85	0.92
Road Surface Character									
Straight and level	47,769	74.1	57.44	53,565	72.4	62.65	**1.09**	1.07	1.12
Straight not level	11,932	18.5	14.35	13,727	18.6	16.06	**0.99**	0.97	1.02
Curved	4,186	6.5	5.03	6,006	8.1	7.03	**0.79**	0.75	0.82
Posted Speed Limit									
Less than 35 mph	22,447	34.8	26.99	25,877	35.0	30.27	**0.99**	0.97	1.01
35-60 mph	33,384	51.8	40.15	37,812	51.1	44.23	**1.03**	1.01	1.05
More than 60 mph	8,599	13.3	10.34	10,269	13.9	12.01	**0.96**	0.93	0.98

Table 5 for Vehicle-Related Characteristics

Vehicle Related Characteristic	Young Female Drivers			Young Male Drivers			Young Female versus Young Male Drivers		
	Num.	%	Crashes per 1,000 drivers	Num.	%	Crashes per 1,000 drivers	**ORs**	95% CI Lower	95% CI Upper
Vehicle Type									
Automobile	49,282	76.5	59.26	43,557	58.9	50.95	**2.27**	2.21	2.32
Van	1,825	2.8	2.19	2,088	2.8	2.44	**1.00**	0.94	1.07
Pickup-truck, camper-rv	3,920	6.1	4.71	18,650	25.2	21.81	**0.19**	0.18	0.20
Sport utility vehicle	9,403	14.6	11.31	9,663	13.1	11.30	**1.14**	1.10	1.17
Vehicle Age									
4 years or newer	13,728	21.3	16.51	11,864	16.0	13.88	**1.42**	1.38	1.46
5-9 years	29,039	45.1	34.92	19,164	39.4	22.42	**1.26**	1.23	1.29
10-14 years	20,556	31.9	24.72	26,250	35.5	30.70	**0.85**	0.83	0.87
Year 15 or older	5,889	9.1	7.08	12,331	16.7	14.42	**0.50**	0.48	0.52
Number of Occupants									
Only driver	43,377	67.3	52.16	50,197	67.9	58.72	**0.97**	0.95	0.99
Driver and passengers	20,867	32.4	25.09	23,543	31.8	27.54	**1.03**	1.00	1.05

Table 6 Crash-Related Characteristics

Crash-Related Characteristic	Young Female Drivers			Young Male Drivers			Young Female versus Young Male Drivers		
	Num.	%	Crashes per 1,000 drivers	Num.	%	Crashes per 1,000 drivers	**ORs**	95% CI Lower	95% CI Upper
Injury Severity									
Fatal injury	82	0.1	0.10	216	0.3	0.25	**0.43**	0.33	0.56
Disabled injury	671	1.1	0.81	756	1.1	0.88	**1.01**	0.91	1.12
Injury	4,289	6.9	5.16	4,348	6.1	5.09	**1.13**	1.08	1.18
Possible injury	5,630	9.0	6.77	4,024	5.6	4.71	**1.65**	1.58	1.72
Not injured	51,991	83.0	62.52	62,025	86.9	72.55	**0.73**	0.71	0.76
Ejection									
Ejected	218	0.3	0.26	431	0.5	0.50	**0.58**	0.49	0.68
Not ejected	62,051	96.3	74.62	70,659	95.5	82.65	**1.22**	1.15	1.28
Trapped	414	0.6	0.50	453	0.6	0.53	**1.05**	0.92	1.20
Vehicle Damage									
Not damage	913	1.4	1.10	1,350	1.8	1.58	**0.77**	0.71	0.84
Minor damage	15,766	24.5	18.96	17,086	23.1	19.99	**1.08**	1.05	1.10
Functional	22,716	35.3	27.32	24,521	33.2	28.68	**1.10**	1.07	1.12
Disabling	20,723	32.2	24.92	24,322	32.9	28.45	**0.97**	0.95	0.99
Destroyed	3,775	5.9	4.54	6,003	8.1	7.02	**0.70**	0.67	0.73
Vehicle Maneuver Before Un-stabilized Situation									
Straight-following	38,532	59.8	46.34	45,344	61.3	53.04	**0.94**	0.92	0.96
Turn or changing lanes	11,056	17.2	13.30	12,941	17.5	15.14	**0.98**	0.95	1.00
Avoiding maneuver	2,297	3.6	2.76	3,324	4.5	3.89	**0.78**	0.74	0.83
Stopped, parking or backing	11,643	18.1	14.00	10,926	14.8	12.78	**1.28**	1.24	1.31
Accident Class									
Collision with vehicle	50,193	77.9	60.36	52,266	70.7	61.14	**1.46**	1.43	1.50
Collision with object	7,983	12.4	9.60	13,195	17.8	15.43	**0.65**	0.63	0.67
Collision with animal	3,713	5.8	4.47	4,603	6.2	5.38	**0.92**	0.88	0.96
Collision with pedestrian	356	0.5	0.43	394	0.5	0.46	**1.04**	0.90	1.20
Non-collision & overturned	2,114	3.3	2.54	3,438	4.7	4.02	**0.7**	0.66	0.73
Manner of Collision									
Head on	1,451	2.2	1.74	1,842	2.5	2.15	**0.9**	0.84	0.97
Rear end	21,643	33.6	26.03	21,841	29.5	25.55	**1.21**	1.18	1.23
Angle side impact	19,706	30.6	23.70	19,939	27	23.32	**1.19**	1.17	1.22
Sideswipe	4,448	6.9	5.35	4,877	6.6	5.70	**1.05**	1.01	1.10
Backed into	1,322	2	1.59	1,232	1.7	1.44	**1.24**	1.14	1.34

Table 7 Contributory Causes

Contributory Causes	Young Female Drivers			Young Male Drivers			Young Female versus Young Male Drivers		
	Num.	%	Crashes per 1,000 drivers	Num.	%	Crashes per 1,000 drivers	**ORs**	95% CI	
								Lower	Upper
Driver Action Related									
Speeding	10,058	15.6	12.10	11,490	15.5	13.44	**1.00**	0.98	1.03
Failure to yield right of way	5,930	9.2	7.13	6,806	9.2	7.96	**1.00**	0.96	1.04
Disregarded traffic signs/signals	2,892	4.5	3.48	3,306	4.5	3.87	**1.00**	0.95	1.06
Turning or lane changing	2,170	3.4	2.61	2,531	3.4	2.96	**0.98**	0.93	1.04
Improper action	1,970	3.1	2.37	2,247	3.0	2.63	**1.01**	0.95	1.07
Aggressive driving	1,489	2.3	1.79	1,750	2.4	2.05	**0.98**	0.91	1.05
Avoidance/ evasive or slow	1,779	2.8	2.14	1,997	2.7	2.34	**1.02**	0.96	1.09
Driver Condition Related									
Alcohol impaired	2,280	3.5	2.74	2,712	3.7	3.17	**0.96**	0.91	1.02
Ill, falling asleep or fatigued	970	1.5	1.17	1,138	1.5	1.33	**0.98**	0.90	1.07
Driver Distractions Related									
Inattention	13,424	20.8	16.14	15,426	20.9	18.04	**0.99**	0.97	1.02
In vehicle distraction	1,900	3.0	2.28	2,172	2.9	2.54	**1.00**	0.94	1.07
Environmental Related									
Animal	2,964	4.6	3.56	3,545	4.8	4.15	**0.96**	0.91	1.01
Weather related	2,719	4.2	3.27	3,085	4.2	3.61	**1.01**	0.96	1.07
Vision obstruction	756	1.2	0.91	885	1.2	1.04	**0.98**	0.90	1.08

Table 8 Injury Severity Models

Label	Parameters	Female Young Drivers		Male Young Drivers	
		Coef.	p	Coef.	p
Intercept	Fatal/severe injury	2.465	0.008*	2.582	0.002*
Intercept	Injury	4.962	<.001*	5.054	<0.001*
Intercept	Possible injury	7.551	<.001*	7.086	<0.001*
VALID	If driver has valid license=1, otherwise 0	-0.184	0.002*	-0.014	0.776
RETRIC	If restricted driver license=1, otherwise=0	-0.035	0.332	0.052	0.166
SEATB	If seat belt used=1, otherwise 0	-1.045	<.001*	-1.077	<.001*
AIRB	If air bag deployed=1, otherwise 0	0.919	<.001*	0.813	<.001*
ALOD	If alcohol or drug related=1, otherwise 0	0.421	<.001*	0.511	<.001*
WEATR	If normal weather =1, otherwise 0	-0.001	0.986	0.080	0.234
RURAL	If rural roads=1, otherwise 0	0.316	<.001*	0.190	<.001*
WZONE	If work zone=1, otherwise 0	0.100	0.340	-0.054	0.650
MORNIN	If 5.00 a.m. – 9.00 a.m.=1, otherwise 0	-0.110	0.057	0.031	0.598
DAYT	If 9.00 a.m. – 1.00 p.m.=1, otherwise 0	0.058	0.266	0.003	0.956
AFNOON	If 1.00 a.m. – 5.00 p.m.=1, otherwise 0	0.008	0.863	0.036	0.474
NIGHT	If 9.00 p.m. – 5.00 a.m..=1, otherwise 0	-0.062	0.259	-0.013	0.800
WEEKE	If week ends=1, otherwise 0	-0.107	0.006*	0.010	0.775
OFFR	If off roadway=1, otherwise 0	0.238	<.0001*	0.153	0.001*
INTER	If intersection on roadway=1, otherwise 0	0.053	0.214	-0.011	0.805
CON	If concrete surface=1, otherwise 0	-0.013	0.738	-0.097	0.020*
GRA	If gravel/brick =1, otherwise 0	-0.090	0.173	0.024	0.661
WET	If road surface is wet=1, otherwise 0	-0.120	0.089	-0.152	0.027*
DEBRI	If road surface is debris=1, otherwise 0	-0.343	<.001*	-0.539	<.001*
STNLE	If road not level=1, otherwise 0	0.000	0.995	0.133	0.001*
NSTLE	If curved and level=1, otherwise 0	-0.111	0.076	0.001	0.188
LSPEED	If speed is less than 35 mph=1, otherwise 0	-0.222	<.001*	-0.297	<.001*
HSPEED	If speed is more than 60 mph=1, otherwise 0	0.362	<.001*	0.365	<.001*
BODY	If automobile =1, otherwise 0	-0.020	0.615	0.004	0.918
NEW	If vehicle newer than 4 years =1, otherwise 0	-0.176	<.001*	-0.162	<.001*
OLD	If vehicle older than 15 years =1, otherwise 0	0.306	<.001*	0.188	<.001*
PASSEN	If with passengers =1, otherwise 0	-0.009	0.788	-0.084	0.018*
TEEN	If with teen passengers =1, otherwise 0	0.075	0.102	-0.023	0.618
EJECT	If eject =1, otherwise 0	2.470	<.001*	2.790	<.001*
TRAP	if trapped =1, otherwise 0	2.677	<.001*	3.100	<.001*
NODAM	If vehicle has not damage=1, otherwise 0	-1.228	<.001*	-2.063	<.001*
MDAM	If has minor damage=1, otherwise 0	-1.998	<.001*	-2.164	<.001*
FUNCT	If vehicle is functioning =1, otherwise 0	-1.461	<.001*	-1.564	<.001*
DISTRO	If vehicle is destroyed =1, otherwise 0	1.087	<.001*	1.189	<.001*
STFOLL	If straight following roads=1, otherwise 0	0.121	0.009*	0.173	<.001*
AVOILD	If avoidance or slow =1, otherwise 0	0.172	0.035*	0.088	0.239
STOPB	If stopped or backing=1, otherwise 0	0.385	<.001*	0.171	0.050
OVERTN	If non-collision or overturned=1, otherwise 0	0.219	0.001*	0.025	0.652
PED	If collision with pedestrians=1, otherwise 0	-1.389	0.020*	-0.077	0.849
CVEHI	If collision with a vehicle=1, otherwise 0	-0.185	0.082	-0.189	0.033*
ANIM	If collision with animal=1, otherwise 0	-1.705	<.001*	-1.722	<.001*
HEAD	If head on collision=1, otherwise 0	0.732	<.001*	0.582	0.110
REAR	If rear collision=1, otherwise 0	-0.073	0.502	-0.300	0.002*
ANGLE	If angle collision=1, otherwise 0	0.239	0.025*	0.152	0.111
WIPE	If sideswipe collision=1, otherwise 0	-0.197	0.138	-0.171	0.167
BACK	If collision when backing up=1, otherwise 0	-1.465	<.001*	-1.173	0.007*
Likelihood Ratio		9,666	<.001	13,243	<.001
Score		13,397	<.001	18,720	<.001
AIC		30,280		43,954	
SC		30,724		43,981	
-2logL		30,182		43,948	

* Significant at 95% confidence level