Teenage driver crash incidence and factors influencing crash injury by rurality ☆

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ARTICLE INFO

ABSTRACT

Background: Previous research has identified teenage drivers as having an increased risk for motor-vehicle crash injury compared with older drivers, and rural roads as having increased crash severity compared with urban roads. Few studies have examined incidence and characteristics of teen driver-involved crashes on rural and urban roads. *Methods:* All crashes involving a driver aged 10 through 18 were identified from the Iowa Department of Transportation crash data from 2002 through 2008. Rates of overall crashes and fatal or severe injury crashes were calculated for urban, suburban, rural, and remote rural areas. The distribution of driver and crash characteristics were compared between rural and urban crashes. Logistic regression was used to identify driver and crash characteristics associated with increased odds of fatal or severe injury among urban and rural crashes. *Results:* For younger teen drivers (age 10 through 15), overall crash rates were higher for more rural areas, although for older teen drivers (age 16 through 18) the overall crash rates were lower for rural areas. Rural teen crashes were nearly five times more likely to lead to a fatal or severe injury crash than urban teen crashes. Rural crashes were more likely to involve single vehicles, be late at night, involve a failure to yield the right-of-way and crossing the center divider. *Conclusions:* Intervention programs to increase safe teen driving in rural areas need to address specific risk factors associated with rural roadways. *Impact on Industry:* Teen crashes cause lost work time for teen workers as well as their parents. Industries such as safety, health care, and insurance have a vested interest in enhanced vehicle safety, and these efforts should address risks and injury differentials in urban and rural roadways.

1. Introduction

Rural roadways have higher crash incidence and crash injury rates than other types of roadways (Muellman & Mueller, 1996; National Highway Traffic Safety Administration, 2001; Peek-Asa, Zwerling, & Stallones, 2004; Zwerling et al., 2005). This differential has been attributed to many factors including road design (Graham, 1993; Karlaftis & Golias, 2002), reduced use of safety devices (Baker, Clarke, & Brandt, 2000; Lundell, 2003; Zwerling et al., 2001), reduced enforcement of traffic safety laws, and prolonged access to acute medical care (Grossman et al., 1997; Maio, Green, Becker, Burney, & Compton, 1992; Peek-Asa et al., 2004; Rogers et al., 1997). Although several studies have examined overall trends for rural roadway crashes, few studies have identified populations that could be particularly vulnerable to the challenges of driving in the rural environment.

Teenage drivers are involved in a disproportionate number of motor-vehicle crashes. The National Highway Traffic Safety Administration (2006) estimates that per mile, young drivers are involved in three times as many fatal crashes as all other drivers. Motor-vehicle crashes are also the leading cause of death for teens, accounting for approximately 35% of deaths in this age group (Centers for Disease Control and Prevention, 2010).

Teenage drivers may be differentially vulnerable to crashes on rural roads because of their inexperience and lack of maturity compared with older and more experienced drivers (Mayhew, Simpson, & Pak, 2003; McCartt, Mayhew, Braitman, Ferguson, & Simpson, 2009). Challenges such as gravel surfaces, animals in the roadway, narrow roads, and sharp ungraded turns require additional driver experience to safely negotiate. In addition, teens may be less likely to use safety devices, such as seat belts (Williams & Shabanova, 2002).

Few studies have examined crash incidence and injury outcomes on rural and non-rural roadways for teenage drivers. A study using the

Fatality Analysis Reporting System to examine fatal crashes that involved at least one driver younger than 15 in North Dakota found a strong correlation between crash rate and measures of rurality in this small population (Vachal & Malchose, 2009). Chen and colleagues (2009) studied urban and rural teen drivers in New South Wales, Australia and found urban teen drivers to have higher crash incidence than rural teen drivers. They also found that rural teen drivers had increased incidence of single vehicle crashes, which are associated with increased potential for injury. Kmet and Macarthur (2006) found a three-fold increased risk for hospitalization and more than a five-fold increase in risk for fatality in rural compared with urban children involved in a motor-vehicle collision. The purpose of this study is to examine the characteristics of rural and urban motor-vehicle crashes involving fatality or severe injury in a population of young and teen-aged drivers in a predominantly rural state.

2. Methods

2.1. Study design and population

This retrospective study analyzes motor-vehicle crashes reported in the Iowa Crash Database for the 10 year period from 1995 through 2004. The Iowa Crash Database is maintained by the Iowa Department of Transportation, Office of Driver Services (ODS) and includes all investigating police officer's reports of motor-vehicle crashes. The database includes separate hierarchically linked data files that describe the vehicles, the drivers, the injuries, the roadway, and the crash environment.

The study population included Iowa drivers aged 10 through 18 involved in crashes in the state of Iowa. Although drivers are not legally allowed to drive in Iowa until age 14, and then only with a special School Permit, the crash database included a sufficient number of unlicensed drivers under the age of 15 to statistically analyze.

2.2. Variables

The main outcome variables for this analysis were overall crashes and fatal or severe injury crashes. Overall crashes included any crash in the database that involved a teenage driver. Fatal and severe injury crashes were included as one category because fatal crashes alone yielded small numbers. Fatal or severe injury crashes included any reported crash with a teen driver that led to fatal or severe injury of any party involved. Severe injury crashes were identified based on the designation of a fatality or incapacitating injury on the crash report. These designations are made by the responding police officers who chose between the categories of: fatal, incapacitating, non-incapacitating, possible injury, and no injury. Thus, reported rates are interpreted as the rate of fatal and severe crash incidence by teen drivers, which do not represent the rate of teenagers fatally or severely injured in a crash. This was the desired outcome variable because our hypothesis is to examine teenage driver factors leading to overall and severe impact crashes, rather than to examine medical outcomes for teenagers in crashes.

The main exposure variable for this analysis was rurality. Two methods were used to determine rurality: population-based crash rates used county-level urban influence and crash location used specific roadway segments designations. Population-based crash rates were calculated by level of urban influence based on the county of the crash. The population denominators were the number of teens in each county based on the 2000 Census. Counties were categorized based on Urban Influence Codes, which assign a value of rurality by county. Counties were categorized as urban (UIC = 1,2) suburban (UIC = 3-7), rural (UIC = 8-10), and rural remote (UIC = 11 = 12) (Economic Research Services, 2003).

We also examined rurality of the crash location. Individual crash locations were categorized as rural or urban based on the roadway designation of the crash location. A total of 1,397 (1.6%) crashes were excluded from this portion of the analysis because specific crash location was not reported. Individual crash locations were identified as urban or rural based on the type of roadway segment on which the crash occurred. The crash was urban if it occurred on a roadway segment within or touching a city corporate limit, with a city defined as being an incorporated area with a population of at least 5,000. Otherwise the crash was rural.

Driver variables were examined for the teenage driver. Driver information included driver age, gender, restraint use, whether or not the driver was tested for alcohol use and, if so, results of the alcohol test, and teen driver ejection. Crash characteristics included day and time of the crash, number of vehicles involved in the crash, crash configuration, and teen driver actions leading to the crash. Crash configuration included rear-end, broadside, angle on a left turn, sideswipe, non-collision (single vehicle), head-on, and all other. Teen driver actions listed as a contributing circumstance to the crash were examined, whether or not the driver was charged with a violation. Driver actions included failure to yield the right-of-way; following too closely; lost control; reckless driving including speeding, swerving, evading, or overcorrection; crossing center or traveling the wrong way; animal collision; and all other. The primary contributing cause for the crash was examined to create mutually exclusive categories.

Environmental characteristics including season, lighting, and road surface conditions were examined and found not to differ by rurality; these results were not further examined in the analysis. Speed was not included because the data were too frequently missing and, even when present, speed estimates are often unreliable. Instead, speed was examined as a contributing cause of the crash and a reason for driver citation.

2.3. Analysis

Crash incidence rates were calculated for the age groups of 10 through 15 and 16 through 18 by dividing the number of teens involved in a reported crash by the number of teens in Iowa in each age group in each rurality category. Severe and fatal crash injury rates were calculated for these age categories by dividing the number of teens involved in severe and fatal crashes by the population.

Driver and crash characteristics were examined for all crashes and for severe/fatal injury crashes. Case Fatality Rates were calculated as the number of fatal and severe crashes divided by the total number of reported crashes, representing the number of fatal/severe crashes per 100 total crashes. Odds ratios and 95% confidence intervals predicting the odds for severe and fatal injury crashes among all reported crashes were calculated using logistic regression models. Models for urban and rural crashes were run separately so that effect estimates for increased injury odds could be compared between the two categories. The proportion of fatal and severe injury crashes per 100 reported crashes was calculated for each variable describing driver and crash characteristics, stratified by urban and rural crashes.

3. Results

3.1. Incidence of teen crashes by rurality

Over 82,000 crashes among teens aged 16 through 18 and over 6,000 crashes among teens aged 10 through 15 were reported in Iowa from 2002 through 2008, for an average of more than 11,000 teen crashes per year (Table 1). The average annual teen driver crash involvement rate was 3.45 per 1,000 teens aged 10 through 15 and 87.45 per 1,000 teens aged 16 through 18. For younger drivers, the crash involvement rate was elevated by 11% for suburban and remote rural areas and 20% for rural areas when compared with urban areas. For older teens, the crash involvement rate decreased with increasing rurality. For example, rural teens were 15% less

Table 1
Teen crash rates by urbanization level of the county in which the crash occurred, Iowa, 2002 – 2008.

Urban/Rural Class.	Teen Population[a]		age 10 - 15			age 16 - 18		
	age 10 -15	age 16- 18	n[b]	Average annual Rate[c]	Rate Ratio (95% CI)	n[b]	Average annual Rate[c]	Rate Ratio (95% CI)
All Crashes								
Urban	131059	69459	2966	3.23	1.00	47727	98.16	1.00
Suburban	64772	33992	1627	3.59	1.11 (1.04 – 1.18)	17123	71.96	0.73 (0.72 – 0.75)
Rural	48252	25518	1307	3.87	1.20 (1.12 – 1.27)	14870	83.25	0.85 (0.83 – 0.86)
Remote rural	10223	5674	257	3.59	1.11 (0.97 – 1.25)	2705	68.11	0.69 (0.67 – 0.72)
Total	254306	134643	6157	3.45		82425	87.45	
Fatal and Severe Crashes								
Urban	131059	69459	115	0.13	1.00	1364	2.81	1.00
Suburban	64772	33992	121	0.27	2.13 (1.59 0 2.67)	828	3.48	1.24 (1.13 – 1.34)
Rural	48252	25518	90	0.27	2.13 (1.24 – 2.71)	617	3.45	1.23 (1.14 – 1.34)
Remote rural	10223	5674	17	0.24	2.00 (0.93 – 2.86)	138	3.47	1.24 (1.02 – 1.46)
Total	254306	134643	343	0.19		2947	3.13	

[a] 2000 Census population.
[b] Numbers represent number of drivers rather than crashes.
[c] Rates are per 1,000 population.

likely (RR = 0.85; 95% CI = 0.83 – 0.86) and remote rural teens were 31% less likely (OR = 0.69; 95% CI = 0.67 – 072) to be involved in a crash than urban teens.

The fatal and severe injury crash rate for teen drivers was 0.19 per 1,000 teens aged 10 through 15 and 3.13 per 1,000 teens aged 16 through 18. For teens aged 10 through 15, fatal and severe crash rates were over two times higher among suburban, rural, and remote rural teens than in urban teens, although this increase was not statistically significant for remote rural teens. For teens aged 16 through 18, fatal and severe crashes were more than 20% higher for suburban, rural, and remote rural teens compared with urban teens.

3.2. Driver characteristics

For every 100 urban crashes involving a teen driver, nearly two led to a fatal or severe injury, compared with over nine for rural teen crashes (Table 2). Rural teen crashes were 4.7 times (95% CI = 4.36 – 5.03) more likely to lead to a fatal or severe crash than urban teen crashes.

Over 90% of teen drivers in crashes were between the ages of 16 and 18, although a slightly higher percentage of rural teens (9.8%) than urban teens (6.0%) were 15 and under (Table 2). Age was not associated with increased odds for being in a severe crash for urban teens, but younger drivers had an increased risk for severe crashes than older drivers in rural crashes. A slightly higher percentage of males than females were involved in crashes for both urban and rural crashes. Odds of a severe crash were not elevated for young men over young women in urban areas, but young men had a 30% increased odds for a severe crash than young women in rural crashes. Gender and age were controlled in the remaining odds ratio calculations.

Restraint use was unknown for nearly 80% of urban and nearly 60% of rural crashes. This high proportion of unrecorded restraint use is a

Table 2
Driver characteristics and odds for injury[1] in urban and rural motor vehicle crashes involving a teen driver, Iowa (2002 - 2008; n = 87,185).

Risk Factor	Urban crash			Rural crash		
	Total Crashes	Case Fatality Rate	Odds ratio for injury[a]	Total Crashes	Case Fatality Rate	Odds ratio for
	n (%)	(% severe crashes)	(95% CI)[b]	n (%)	(% severe crashes)	injury[a] (95% CI)[b]
Total	65144	1.94	NA	22041	9.11	NA
Driver age						
10 -15	3890 (6.0)	1.88	Ref.	2152 (9.8)	12.45	Ref.
16-18	61254 (94.0)	1.94	1.03 (0.81 - 1.31)	19889 (90.2)	8.75	0.67 (0.58 - 0.77)
Gender						
Male	33473 (51.4)	1.90	0.96 (0.86 - 1.08)	11981 (54.4)	9.93	1.27 (1.15 - 1.39)
Female	31567 (48.5)	1.97	Ref.	10032 (45.5)	8.05	Ref.
Not reported	104 (0.2)	0.96	0.48 (0.07 - 3.47)	28 (0.1)	35.71	6.27 (2.88 - 13.65)
Restraint Use						
Yes	11507 (17.7)	5.23	Ref.	7219 (32.8)	13.89	Ref.
No	1611 (2.5)	16.64	3.6 (3.09 - 4.21)	1737 (7.9)	36.44	3.43 (3.05 - 3.87)
Other/Unknown	52026 (79.9)	0.75	0.14 (0.12 - 0.16)	13085 (59.4)	2.84	0.18 (0.16 - 0.20)
Tested for Alcohol Use						
Yes	1172 (1.8)	13.65	9.09 (7.60 - 10.87)	1413 (6.4)	31.71	5.63 (4.96 - 6.38)
No	60168 (92.4)	1.76	Ref.	19544 (88.7)	7.74	Ref.
Refused	58 (0.1)	10.34	6.77 (2.90 - 15.82)	35 (0.2)	5.71	0.76 (0.18 - 3.17)
Not known/reported	3746 (5.8)	1.01	0.57 (0.41 - 0.79)	1049 (4.8)	4.29	0.54 (0.40 - 0.74)
If tested, BAC results						
Positive	754 (64.3)	9.02	0.36 (0.25 - 0.50)	736 (52.1)	25.95	0.6 (0.47 - 0.73)
Negative	418 (35.7)	22.01	Ref.	677 (47.9)	37.96	Ref.
Ejected from vehicle						
Yes	454 (0.7)	27.09	6.01 (4.84 - 7.47)	630 (2.9)	53.97	6.18 (5.23 - 7.30)
No	16841 (25.9)	5.80	Ref.	9853 (44.7)	15.64	Ref.
Not known/reported	47849 (73.4)	0.34	0.06 (0.05 - 0.07)	11558 (52.4)	1.10	0.06 (0.05 - 0.07)

a) Injury included crash reports that listed any injury as fatal or severe which were compared to no, 'minor' or 'possible' injury. 'Possible' injury indicates that no visible injury was present and medical response was sought.
b) Models for age controlled for gender; models for gender controlled for age; all other models controlled for age and gender.

feature of Iowa's police crash reporting system, which only requires reporting of restraint use for injury crashes and for injured occupants. Among those with known restraint use, teens in both urban and rural crashes had more than a three-fold increase in the odds of a severe injury crash when a restraint was not worn. Drivers with unknown seat belt use were less likely to be injured than those wearing seat belts, indicating that seat belt status is less likely to be reported in less severe crashes.

A higher proportion of rural teens (6.4%) than urban teens (1.8%) were tested for alcohol use. Urban teens who were tested for alcohol use were 9.09 (95% CI = 7.60 – 10.87) times more likely to be in a severe injury crash than those not tested, and rural teens tested for alcohol were 5.63 (95% CI = 4.96 – 6.38) times more likely to be in a severe injury crash, which most likely indicates that breath alcohol tests are more likely to be conducted in more severe crashes. Refusal of the BAC test, although uncommon, resulted in an increased odds for a severe injury crash of 6.77 in urban crashes, but refusal was not associated with increased odds of a severe injury crash for rural crashes. Among those tested, a higher proportion of urban (64.3%) than rural (52.1%) teens were positive. However, both urban and rural teens who had a positive alcohol test were less likely to be involved in a severe injury crash. Since the injury rates are not specifically for the teen driver's injury, this trend could occur if severely injured teen drivers were not likely to be tested, perhaps because they were receiving medical treatment.

Drivers were ejected from the vehicle in 0.7% of urban and 2.9% of rural teen crashes. When ejected, the case fatality rate for rural teens was 54 per 100 crashes, which corresponds to an increased odds of severe injury of 6.18 (95% CI = 5.23 – 7.30) compared with non-ejected rural teen drivers. Urban teen drivers who were ejected had an increased odds of injury of 6.01 (4.84 – 7.47).

3.3. Crash characteristics

During weekdays, a higher proportion of rural crashes (38.4%) than urban crashes (29.9%) occurred during the evening and night (Table 3). The highest case fatality rates were for crashes occurring from midnight to 6 a.m. for both weekdays and weekends. Compared with crashes that occurred between 6 a.m. and 3 p.m. (roughly school hours), early morning crashes led to an increased odds of injury of 2.75 (95% CI = 1.97 – 3.82) for urban crashes and 1.38 (95% CI 1.10 – 1.74) for rural crashes. Late night weekday crashes led to an increased odds for injury for urban but not rural crashes. Trends were similar for weekends.

Single-vehicle crashes were far more frequent among rural crashes (65.3% of crashes) than urban crashes (10.1% of crashes). Single-vehicle crashes were associated with a five-fold increased injury odds in urban crashes but did not have increased injury odds in rural crashes. Rear-end (35.1%) and broadside (28.3%) collisions were the most frequent crash configurations in urban crashes, while non-collision (64.9%) and rear-end (12.3%) were the most frequent rural crash configurations. Although broadside collisions were a less frequent configuration in rural crashes, they were associated with an increased odds for injury (OR = 1.81; 95% CI = 1.58 – 2.09) for rural and a decreased odds for injury (OR = 0.30; 95% CI = 0.26 – 0.35) for urban crashes. Head-on collisions were associated with a 4.5-fold increase in injury in rural crashes but not with increased injury severity in urban crashes.

Excluding non-specific contributing causes, failure to yield the right-of-way was the most common contributing cause to the crash for both urban (32.6%) and rural (57%) teen drivers. Running off the road and/or losing control of the vehicle was the second most frequent contributing cause for urban teen drivers and accounted for

Table 3
Crash characteristics and odds for injury[1] in urban and rural motor vehicle crashes involving a teen driver, Iowa (2002 - 2008; n = 87,185).

Risk Factor	Urban crash			Rural crash		
	Total Crashes	Case Fatality Rate	Odds ratio for injury[a]	Total Crashes	Case Fatality Rate	Odds ratio for injury[a]
	n (%)	(% severe crashes)	(95% CI)[b]	n (%)	(% severe crashes)	(95% CI)[b]
Weekday						
0000 - 0600	937 (1.8)	4.38	2.75 (1.97 - 3.82)	845 (5.6)	11.95	1.38 (1.10 - 1.74)
0600 - 1459	21092 (41.1)	1.65	Ref.	5384 (35.9)	8.86	Ref.
1500 - 1659	13969 (27.2)	1.50	0.91 (0.76 - 1.08)	3022 (20.1)	7.91	0.88 (0.75 - 1.03)
1700 - 2359	15379 (29.9)	2.10	1.28 (1.10 - 1.49)	5766 (38.4)	8.08	0.91 (0.79 - 1.04)
Weekend						
0000 - 0600	1418 (10.4)	4.02	2.11 (1.51 - 2.96)	1304 (18.8)	13.50	1.48 (1.19 - 1.84)
0600 - 1459	4862 (35.7)	1.93	Ref.	2037 (29.4)	9.72	Ref.
1500 - 1659	2115 (15.6)	1.56	0.82 (0.54 - 1.20)	797 (11.5)	10.79	1.12 (0.86 - 1.46)
1700 - 2359	5209 (38.3)	2.86	1.49 (1.15 - 1.93)	2782 (40.2)	9.45	0.99 (0.82 - 1.21)
Number of Vehicles						
Single	6607 (10.1)	6.40	4.83 (4.28 – 5.45)	14399 (65.3)	9.03	0.97 (0.88 – 1.06)
Multiple	58537 (89.9)	1.43	Ref.	7642 (34.7)	9.26	Ref.
Leading Crash Configurations						
Rear-end	22855 (35.1)	0.80	0.12 (0.10 - 0.14)	2717 (12.3)	3.35	0.35 (0.28 - 0.44)
Broadside	18427 (28.3)	2.04	0.30 (0.26 - 0.35)	1808 (8.2)	15.21	1.81 (1.58 - 2.09)
Angle on left turn	7322 (11.2)	1.78	0.26 (0.21 - 0.32)	570 (2.6)	6.14	0.66 (0.47 - 0.94)
Sidesweep	7288 (11.2)	0.73	0.11 (0.08 - 0.14)	1613 (7.3)	6.14	0.66 (0.54 - 0.82)
Non-collision	6637 (10.2)	6.33	Ref.	14314 (64.9)	9.03	Ref.
Head-on	1440 (2.2)	5.76	0.90 (0.70 - 1.14)	647 (2.9)	30.60	4.45 (3.73 - 5.32)
All Other	1175 (1.8)	1.53	0.23 (0.14 - 0.36)	372 (1.7)	4.57	0.50 (0.31 - 0.81)
Leading Driver Actions						
Failure to Yield Right of Way	21222 (32.6)	2.54	Ref.	12558 (57.0)	10.93	Ref.
Following Too Closely	119 (0.2)	13.45	5.95 (3.49 - 10.14)	2 (0.01)	0.00	————
Ran Off Road/Lost Control	4577 (7.0)	1.09	0.42 (0.32 - 0.57)	566 (2.6)	3.18	0.27 (0.17 - 0.43)
Reckless/Speed-Related	3736 (5.7)	2.44	0.95 (0.76 - 1.20)	218 (1.0)	8.72	0.79 (0.49 - 1.26)
Swerving/Evading/Overcorrected	683 (1.1)	2.05	0.80 (0.47 - 1.37)	330 (1.5)	9.70	0.88 (0.60 - 1.27)
Cross center/Wrong Way	3922 (6.0)	1.94	0.76 (0.60 - 0.97)	2892 (13.1)	8.02	0.71 (0.61 - 0.82)
Animal Collision	1738 (2.7)	3.11	1.23 (0.92 - 1.63)	37 (0.2)	16.22	1.60 (0.67 - 3.86)
All Other	29147 (44.7)	1.44	0.56 (0.49 - 0.64)	5438 (24.7)	6.05	0.54 (0.47 - 0.61)

a) Injury included crash reports that listed any injury as fatal or major which were compared to no, 'minor' or 'possible' injury. 'Possible' injury indicates that no visible injury was present and medical response was sought.
b) Models for age controlled for gender; models for gender controlled for age; all other models controlled for age and gender.

7.0% of urban crashes; it was the third leading cause accounting for 2.6% of rural teen crashes. Reckless driving and speed-related causes were more common for urban (5.7%) than rural (1.0%) teen drivers. Crossing the center line or going the wrong way, however, was more frequent for rural teen drivers (13.1%) than urban teen drivers (6.0%). Animal collisions were higher in urban (2.7%) than rural (0.2%) crashes.

Case fatality rates for driver actions were higher for rural than urban teen drivers for all causes except following too closely, for which there were only two rural crashes. The odds of injury for different driver actions varied by rurality. Following too closely had the highest odds for injury in urban teen crashes (OR = 5.95; 95% CI = 3.49 – 10.14), followed by animal collisions. For rural teen crashes, running off the road was associated with a decreased odds of injury.

4. Discussion

Crash involvement and crash injury rates for Iowa's teens are high. For every 1,000 teens, nearly 90 were involved in a reported crash and more than three were involved in a fatal/severe injury crash. We examined crash rates from the age of 10 because the crash data indicated that a statistically relevant number of teens starting at this age were reported to be driving during the crash. Very young, non-licensed drivers have not been examined in the literature, but such drivers may be more common in rural areas because they are isolated. Iowa allows teenagers to drive unsupervised as young as 14½ years old through the School Permit, which might contribute to higher than normal crash rates among teens younger than 16 in Iowa.

Overall crash rates for drivers age 10 through 15 were higher in suburban, rural, and remote rural areas when compared with urban areas. For older teens, however, non-urban areas had lower rates. For fatal/severe crashes, rates were elevated for all non-urban areas and were more than twice as high in non-urban than urban areas for younger teen drivers. Increased crash rates by rurality for the younger drivers, which is based on population data rather than vehicle miles travelled, could be influenced by several different trends, including an increase in the percentage of young teens who drive in non-urban than urban areas, an increased number of miles travelled among young drivers in the non-urban areas, or increased risk for crashing in non-urban areas. In a sample of teen drivers in Australia, urban teens were also found to have increased crash incidence (Chen et al., 2009). Chen and colleagues also used individuals, rather than miles travelled, as the rate denominator.

Severe crash rates were higher in suburban, rural, and remote rural areas when compared with urban areas. Trends in suburban, rural, and remote rural severe crashes were similar. This similarity among non-urban areas may be particular to Iowa, which has few population centers and no large metropolitan areas. Outside of towns, "suburban" roadways begin to resemble rural roads very quickly. For other rural states, roadways designated as being in "suburban" counties may also share more features of rural areas than the outlying areas around metropolitan or other population centers. No previous studies have examined variation in rural environments.

Rural teen crashes were nearly five times more likely to lead to a fatal or severe injury crash than urban teen crashes. A study of teen drivers in North Dakota found that teen drivers were six times more likely to be severely injured on rural roads than urban roads (Kmet & Macarthur, 2006). Driver characteristics associated with an increased odds for a fatal or severe crash were similar for urban and rural crashes and included lack of restraint use, being tested for alcohol use, and being ejected. Although odds ratios were similar, case fatality rates indicated that some of these driver characteristics were much more prevalent in rural than in urban crashes. Increased case fatality ratios were consistently higher in rural than urban crashes, but were particularly pronounced for younger drivers, teen drivers not wearing

seat belts, teen drivers tested for alcohol use, and crashes that led to an occupant being ejected from the vehicle. Ejection was associated with the largest case fatality rates and one of the highest increased odds for injury. Ejection is usually associated with high-impact crashes and failure to wear a seat belt. Although ejection is an important risk factor for crashes in both urban and rural areas, it was much more frequent in rural than urban crashes.

Urban and rural differences in crash characteristics reflect the different roadway environments. Single-vehicle crashes were more frequent and more severe in rural than urban crashes, which is consistent with results from Australia (Chen et al., 2009). In rural areas, these are likely associated with loss of control on rural roadways, which can lead to impact with fixed objects on the side of the road or running off the roadway. Broadside collisions were strongly associated with increased odds for injury in rural crashes but not urban crashes. In rural areas, broadside collisions may involve uncontrolled intersections and increased speed when compared with urban intersections, where these are most likely to involve left-turn configurations in controlled intersections. Head-on collisions were also associated with increased odds for injury in rural but not urban crashes. In rural areas, with narrow two-lane roads and less visibility, there may be less time for evasive action and increased collision speed with collision.

This study has several limitations. Only crashes reported to law enforcement officers are included, and reporting may be differential in rural and urban areas. A higher proportion of rural crashes led to severe and fatal injury. While some of this may be due to increased reporting of all crashes in urban areas, this reporting differential is unlikely to account for the differences in crash severity. Reduced seat belt use, increased ejection, and increased single-vehicle crashes contributed to injury severity in rural crashes. The dataset does not include information on some variables important for predicting injury severity, such as restraint use by non-injured occupants, and does not include speed estimates. Missing data makes it difficult to interpret findings for some variables. The findings from the state of Iowa are more likely to be generalizable to rural areas that are relatively flat and based on agricultural economies.

5. Conclusion

These findings are important for prevention because few teen driver interventions have focused on rural roadway risks despite the increased crash risk (Peek-Asa et al., 2004; Zwerling et al., 2005). Driver and crash characteristics differ between rural and urban teen drivers, as do the factors associated with increased odds of fatal and severe injury in a crash.

Acknowledgement

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