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Characteristics of motor vehicle crashes among 14 & 15 year old drivers

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CHARACTERISTICS OF MOTOR VEHICLE CRASHES AMONG 14 & 15 YEAR OLD DRIVERS

by

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A thesis submitted in partial fulfillment
of the requirements for the Master
of Science degree in Epidemiology
in the Graduate College of
The University of Iowa

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CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's thesis of

Morgan Alexandria Price

has been approved by the Examining Committee
for the thesis requirement for the Master of Science
degree in Epidemiology at
the August 2015 graduation.

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ABSTRACT

Objective: In 2010, motor vehicle crashes were the leading cause of death among 13 – 19 year-old males and females in the United States (National Center for Injury Prevention and Control, 2014). The overall goal of this research is to differentiate between measures associated with crashes for young teen drivers, age fourteen to fifteen years on urban and rural roads.

Methods: A retrospective study of motor vehicle crashes among 14 and 15-year old drivers in the state of Iowa was conducted using crash information obtained from the Iowa Department of Transportation for the years of 2001 to 2013. Crash rates were calculated by rurality using Urban Influence Codes (UIC). The total number of crashes and crashes resulting in injury were divided by the population of young teen drivers aggregated at the UIC level. Crash and driver characteristics were analyzed for measures of association to the main outcome, injury using logistic regression. Crash and driver characteristics that were associated with injury at the $p \leq 0.20$ level were eligible for model inclusion.

Results: For every 1,000 young teen drivers age fourteen to fifteen years, nearly 8 were involved in a crash statewide from 2001 - 2013. Half of all crashes in the dataset occurred in an urban area (n = 4327, 51%), while 7% occurred in a suburban area, 29% in a town and 13% in a remote rural area. Results show, for all crashes and crashes resulting in injury, that as the level of rurality increases, rates of crash also increase. Remote rural crashes have the highest crash rate ratio (RR = 1.15, 95% CI: 1.08, 1.22), relative to urban crashes. The presence of multiple teen passengers in the vehicle increased the odds of having a crash that resulted in injury 10.73 times, compared to no passengers being present (95% CI: 7.10, 16.22). Characteristics with the strongest association with injury were single vehicle collisions, crashes that occurred on rural roads, crashes were the driver lost control and crashes were multiple teen passengers were present.

Conclusions: Results from this study highlight the dangerous circumstances that young teen drivers face, especially when driving on rural roads. In order to protect young teen drivers from crashes, there is a need for more restrictions on the number of passengers and the development of prevention methods to make young teen drivers safer.

PUBLIC ABSTRACT

Young drivers are overrepresented in collisions. Although the number of annual deaths is declining, thousands of teens are still injured in motor vehicle crashes each year. Due to limited driving ability, lack of mental development and overall naive behavior at such a young age, young teens, age fourteen to fifteen, potentially have a higher risk of crash compared to older teen drivers. This study examined the factors associated with crashes for young teen drivers, age fourteen to fifteen on urban and rural roads; such factors included the number of vehicles involved in the crash, number of passengers, weather conditions and location of crash.

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LIST OF ABBREVIATIONS

DOT	Department of Transportation
UIC	Urban influence code
RR	Rate ratio
OR	Odds ratio
CI	Confidence interval
GDL	Graduated driver's license

INTRODUCTION

In 1931, Iowa officials approved legislation allowing young teens, 14 and 15 years old, to receive a school license. At that time, the law applied mostly to rural farm children who needed a means to get to and from school. Over 80 years later, the same legislation still stands. In 1931 there were 650,000 registered vehicles in the state of Iowa (Iowa Department of Transportation, 2008). Compare that to the 3.5 million vehicles on the road now, and it is clear the driving environment for these young teens is exponentially more dangerous (Iowa Department of Transportation, 2008).

Contributing to the dangerous driving environment for young teen drivers is the road type that they are driving on; urban or rural roads. Rural roads have higher incidence of fatalities, crash incidence and injury rates compared to other road types (National Highway Traffic Safety Administration [NHTSA], 2010; Zwerling C. P.-A.-W., 2005). In 2010, the fatality rate per 100 million vehicle miles traveled was 2.5 times higher in rural area (1.83) than in urban areas (0.73) (National Highway Traffic Safety Administration [NHTSA], 2010). Young teen drivers are at an even higher risk when driving on rural roads due to minimal experience and a lack of driving skills. Much of current research focuses mainly on teen drivers age 16 – 19, there is a serious need to focus on the younger more vulnerable population instead of having a one size fits all approach and applying findings of older teens to younger teen drivers.

Specific Aims

The long term goal of this research is to reduce crash rates and crash related injuries for young teen drivers. The overall goal of this research is to differentiate between measures associated with crashes for young teen drivers, age fourteen to fifteen on urban and rural roads. The central hypothesis to be examined is that crash rates amongst young teens are higher for those classified as crashing on a rural roads versus having a crash in an urban area.

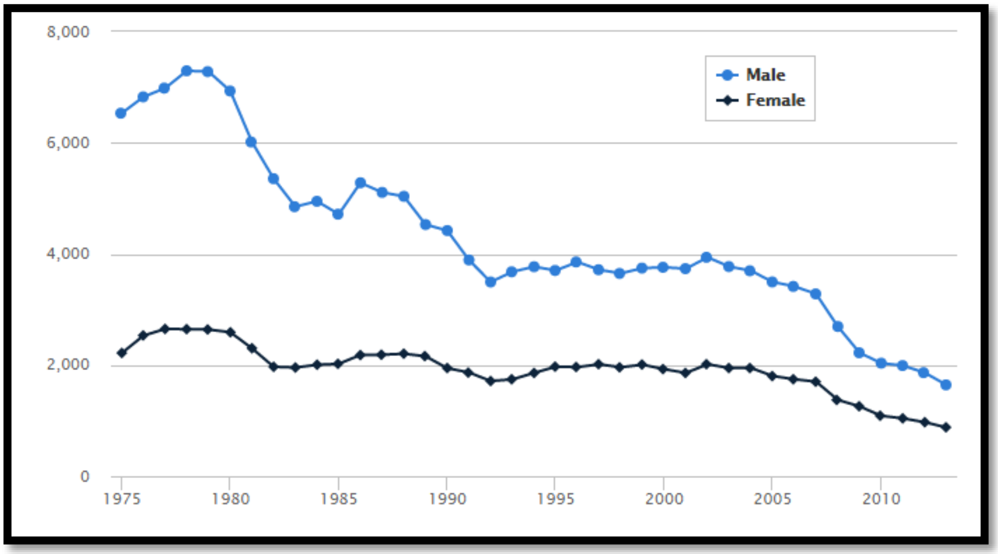
Considering this hypothesis, the specific aims of the proposed work are:

1. Compare the frequency of crashes and the proportion of crashes that lead to injury by rurality for fourteen and fifteen year-old drivers.
2. Identify the association of rural motor vehicle crashes with injury among 14 and 15 year old drivers in Iowa from 2001 to 2013 looking specifically at driver and crash characteristics.

Teen Driving Background

In 2010, motor vehicle crashes were the leading cause of death among 13 – 19 year-old males and females in the United States (National Center for Injury Prevention and Control, 2014). As seen in Figure 1, fatalities due to motor vehicle crash are declining. A total of 2,524 teens age 13 – 19 died in motor vehicle crashed in 2013. Compared to 1975 there has been a 71% decrease. There are 11% fewer crashes compared to 2012 (Insurance Institute for Highway Safety, 2015). However, these numbers do not begin to capture the thousands of teens that are injured in motor vehicle crashes each year. In 2011, 292,000 teens were treated in emergency departments for injuries suffered in motor-vehicle crashes (Centers for Disease Control and Prevention, 2014). Although the number of fatalities is on the decline, young drivers are still at the greatest risk of having a crash, specifically after licensure; permitting independent driving (Mayhew, 2003).

Figure 1: Teenage motor vehicle crash death by gender between the years of 1975 and 2013 (Insurance Institute for Highway Safety, 2015)



Experience & Age

High crash rates amongst teens can be attributed to a lack of experience paired with a lack maturity (Mayhew, 2003). Teenagers are still developing both physically and cognitively. These constant changes undoubtedly contribute to young drivers' behaviors behind the wheel. At the age when driving independently is permitted by law, teens are in the midst of their highest risk taking period of life (Johan, 1986; Jonah, 1990). For teens, the parts of the brain involved in emotional responses are fully active. Simultaneously, parts of the brain involved in keeping emotional, impulsive responses in check are still reaching maturity. These changes result in a tendency to act on impulse without regard for risk (National Institute of Mental Health, 2011). Behind the wheel, these tendencies to partake in risky behaviors are not halted, instead they are heightened. In the driving environment, risky driving behaviors such as speeding, following at short distances, accelerating abruptly, racing, dangerous passing and driving under the influence have all been associated with sensation seeking and aggressiveness in young drivers (Johan, 1986; Jonah, 1990).

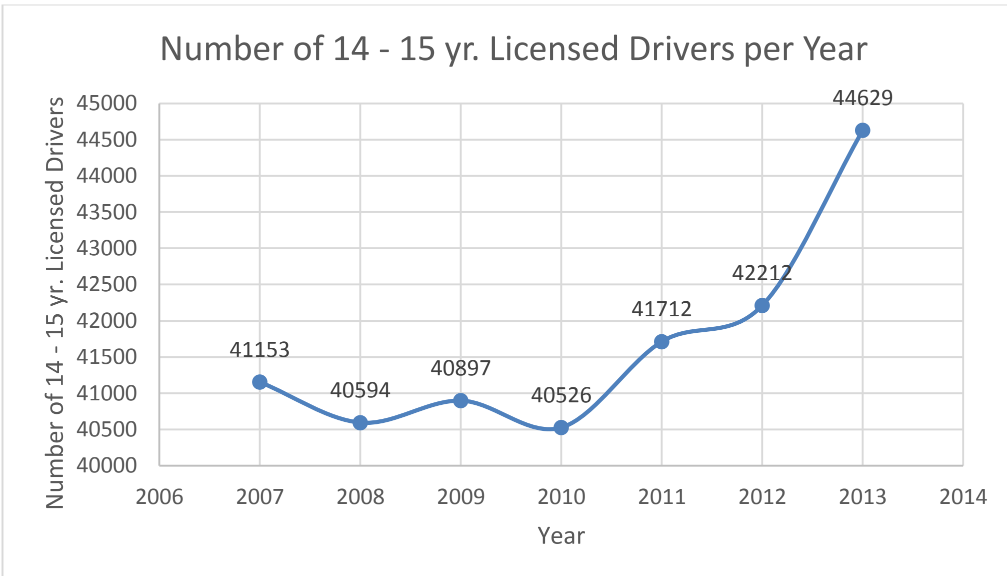
Urban vs. Rural

From 2000 – 2010 Iowa's urban population grew more than 10% (Schulte, 2011). With less of a focus on producing goods and more of a focus on retail, Iowa's population has undergone a shift. Although Iowa's population is classified primarily as urban, 64.02%, the rural population, 35.98%, is still extremely at risk when behind the wheel (State Data Center). According to the Census, 19% of the U.S. population lived in rural areas. However, rural fatalities accounted for 55% of all traffic fatalities in 2010 (National Highway Traffic Safety Administration [NHTSA], 2010). In Iowa alone, rural fatalities accounted for 78% of motor vehicle traffic deaths compared to 22% of urban fatalities (National Highway Traffic Safety Administration [NHTSA], 2010). One study (Peek-Asa C. C., 2010) found that for younger teen drivers age 10 through 15, overall crash rates were higher for more rural areas. Young teens from rural areas who are driving independently have an increase in exposure to driving on dangerous high speed rural roads and therefore have an increase in crash risk. Rural teen crashes were nearly five times more likely to lead to a fatal or severe injury crash than urban teen crashes (Peek-Asa C. C., 2010).

Significance of Study

Research has shown that young drivers are overrepresented in collisions (Mayhew, 2003). Due to the fact that the crash risk for young drivers is high, much research has been conducted and much has been learned about the factors related to teen driving. However, this body of research focuses mainly on teen drivers age 16 – 19. Little is known about young teen drivers age 14 to 15. As seen in Figure 2, the number of 14 and 15 year old drivers seeking licensure is continuously increasing in Iowa. These increasing numbers of young teens are exposed to the same driving environment as 16-19 year old drivers. However their risk could potentially be higher due to their limited driving ability, lack of mental development and overall naive behavior at such a young age. We hypothesized that this population is at high risk for crashes due to their young age, lack of driving experience, and lack of maturity. Results from this study will help fill the gap in knowledge that exists about this population of young teen drivers. This research aims to better understand and identify measures associated with crashes for young teen drivers differentiating between urban and rural teens.

Figure 2: The number teens age 14 and 15 with a school permit in the state of Iowa by year from 2007 -2013 (Iowa Department of Transportation, 2014)



METHODS

Design & Population

This was a retrospective study of motor vehicle crashes among 14 and 15-year old drivers in the state of Iowa. Crash information was obtained from the Iowa Department of Transportation for the years of 2001 to 2013. Motor vehicle crashes occurring in the state of Iowa that resulted in death, injury or property damages of $1500 or more are reported using the Iowa Accident Report form (Iowa Department of Transportation , 2015). Each reported crash is investigated by an Iowa law enforcement officer unless reported by the driver. Information collected in the accident report form is then compiled into a large database. These data include descriptive variables on location of crash, injuries incurred, vehicles and people involved in the crash as well as major causes that led to the crash. The database is organized hierarchically with individual information nested with vehicle information nested within crash information.

The study population for this research was teen drivers aged fourteen to fifteen, which is the period of legal driving prior to full licensure (unsupervised driving). The study population included all reported crashes that involved drivers aged fourteen and fifteen. The unit of analysis was the teen driver.

Variables

The variables at the crash and driver levels that were examined in this study are presented in Table 1 and Table 2.

Table 1: List of variables for analysis of crash factors that contribute to crash

Variables	Description of variable	Variable Options	Variable Type
Day of Week	Day of the week in which the crash occurred	Weekday/Weekend	Binary
Time of crash	Time of day when the crash occurred	Morning Afternoon Evening Night	Categorical
Manner of collision	Type of collision that occurred	Non-collision Head-on Rear-end Angle Sideswipe	Categorical
Number of vehicles	Number of vehicles involved in crash	Single/Multiple	Binary
Weather	Weather conditions that contributed to crash	Clear/ Not Clear	Binary
Road surface condition	Road surface conditions that contributed to crash	Dry/ Not Dry	Binary

Day of the week was collapsed into a binary variable: weekday (Monday through Friday) and weekend (Saturday and Sunday). Time of crash was categorized into four groups: morning (6:00 am – 9:59am), afternoon (10:00 am – 2:59 pm), evening (3:00 pm – 9:59 pm) and night (10:00 pm – 5:59 am). Manner of collision categories were collapsed into five categories: non-collision, head on, rear-end, angle and sideswipe crash. Number of vehicles was categorized as a binary variable: single or multiple vehicle crash. Weather was a binary variable, clear or not clear, and road surface condition was categorized as a binary variable, dry or not dry.

Table 2: List of variables for analysis of driver factors that contribute to crash

Variables	Description of variable	Variable Options	Variable Type
Driver Age	The age of the driver; derived from date of birth and crash date	14 /15 years old	Binary
Driver Gender	The gender of the driver	Male/Female	Binary
Injury Severity	Severity of injuries	Fatal/incapacitating, non-incapacitating/possible, no injury	Categorical
Occupant protection	Type of protection used by occupants involved in crash	None, shoulder and lap belt, lap belt only, shoulder belt only, other	Categorical
Driver's Contributing Circumstances	Circumstances that contributed to the crash due to the driver	No error, failure to yield right of way, improper action, failure to obey traffic signal, speeding; lost control, other	Categorical
Passenger Presence	Determines the presence and age of passenger	No passenger One teen passenger only Multiple teen passengers only At least one adult passenger (regardless of other passengers)	Categorical

Driver age was coded as a binary variable: 14 or 15 years old. Driver gender was dichotomous, male or female. Injury severity was categorized into three groups: fatal and incapacitating injury, non-incapacitating and possible injury, and no injury. Occupant protection was collapsed into five variables: none, shoulder and lap belt, lap belt only, shoulder belt only, and other. Driver's contributing circumstances were collapsed into seven categories: no error, failure to yield right of way, improper action, failure to obey traffic signal, speeding; lost control and other. Passenger presence was categorized into four groups: no passenger, at least one adult passenger (regardless of other passengers), multiple teen passengers only and one teen passenger only. For the purposes of this study, an adult was defined as a person who was at least 21 years old.

Rurality was measured using Urban Influence Codes, which identify rurality at the county level. Urban Influence Code (UIC) is a classification scheme that distinguishes metropolitan counties by population size of their metro area, and nonmetropolitan counties by size of the largest city or town and proximity to metro and micropolitan areas (United States Department of Agriculture, 2013). To determine rurality of the crash, the county code for each crash was linked to the UIC codes. The UIC codes were then categorized into urban (UIC codes 1 & 2), suburban (UIC codes 3-5), town (UIC 6-8) and remote rural (UIC codes 9-12).

Occupant protection was not included in the multivariable model due to the fact that for 51% of crashes in the dataset these data were missing (see Table 4). Vehicle number was excluded from the model because it was too collinear with manner of collision. Over a third of crashes were single vehicle and therefore did not involve a collision with another vehicle. Due to the fact that weather did not meet the criteria for inclusions it was left out of the final model. Despite the fact that gender did not meet the criteria for inclusions, $p = 0.44$, it was included in the multi-variable model due to the evidence in existing literature showing that gender is a strong predictor of crash risk (Williams A. F., 2002). Crashes that involve teen drivers in both cars are double-represented in this database. Unknown and not reported data as well as crashes that were not motor vehicles were coded as missing and excluded from the analysis.

Data Management

All data were acquired from the Iowa Department of Transportation directly using a data acquisition form (Iowa Department of Transportation , 2015). All electronic data was stored on a secure password-protected computer located at the University of Iowa Injury Prevention Research Center. This project was made possible through an ongoing Memorandum of Understanding between the Department of Transportation and the Injury Prevention Research Center and was approved by the University of Iowa Institutional Review Board.

Analysis

Analysis of data was performed using Statistical Analysis Systems (SAS 9.4). Descriptive statistics such as frequencies and means were evaluated first on variables in Table 1 and Table 2. This provided basic information about the study population as well as highlighted inconsistencies in the data. After the data was cleaned, analyses were run to assess the measures of association, both absolute and relative. Cleaning entailed identifying the number of missing variables, checking for outliers, and examining if cell sizes were sufficient for inclusion in further analysis.

Specific Aim 1 Analytic Plan: Crashes were assigned to the county that corresponded to the location of the crash. Counties were then linked to their Urban Influence Code (UIC). UIC codes were grouped into four categories: urban, suburban, town and remote rural. Crashes were then assigned to these four categories. Frequencies were evaluated on the total number of crashes for each UIC category. Frequencies were also evaluated on total number of crashes that resulted in injury for each UIC category.

Population data for each county was obtained from Iowa Census data (Iowa Census Data Tables: Counties, 2010). Census data provided population data for the age-specific category of 14 – 17 years old from 2000 – 2009. However, DOT data accounted for crashes that occurred from 2001 – 2013, so the age-specific county populations needed to be estimated for the missing years. In order to do so, the average annual change was calculated for each year in order to calculate the overall average annual population change. This change was then applied to the out years of 2010-2013 in order to estimate county populations.

An average county population for residents aged 14 and 15 was calculated for 2001 – 2013. Since county-level population data were available for residents in the age category of 14 – 17 only, we estimated our age range by assuming that each age in years was equally represented. Each county's average population of residents aged 14-17 was then divided in half to estimate only the number of 14 and 15 year olds living in each county. UIC population totals were calculated by summing the populations of 14 and 15 year olds from the counties that comprised each UIC group. The proportion of all crashes and crashes resulting in injury per UIC category were then calculated by taking the number of crashes (or crashes resulting in injury) for each UIC category where a crash occurred and dividing that by the aggregate total population of 14 and 15 year olds for the UIC category. Rates and rate ratios were calculated for each UIC group.

Specific Aim 2 Analytic Plan: Using variables from Table 1 & Table 2, frequencies were run in order to determine the distributions. Similar categories were collapsed and the common categories at the crash & driver level were used in the analysis. The main exposure variable was rurality, which was based on UIC categories of crash location. Crash and driver factors were compared by rurality among all crashes and crashes that result in injury. Differences were examined using Chi-square tests.

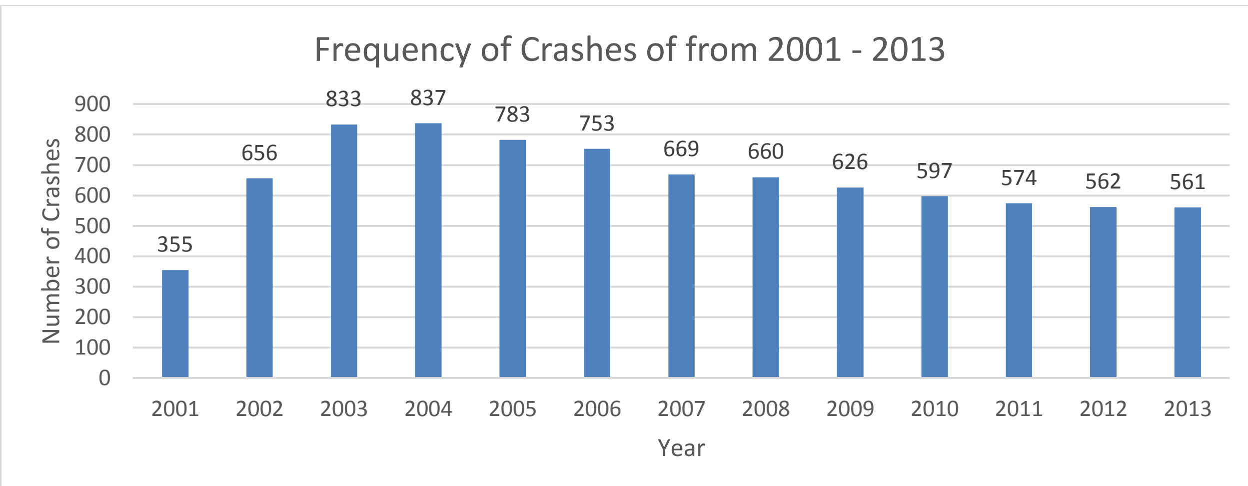
The main outcome variable was injury which, as explained above, was coded as a dichotomous variable. Logistic regression was run to identify the association between injury and crash and driver factors. Crash and driver characteristics with multiple categorical responses were coded as binary or as dummy variables. Crash and driver characteristics that were associated with injury at the $p \leq 0.20$ level were eligible for model inclusion. Crash and driver characteristics that had substantial missing data, more than 40%, were excluded from the analysis. Co-linearity and model fit were examined for final variable selection.

RESULTS

Teen Crashes in Iowa

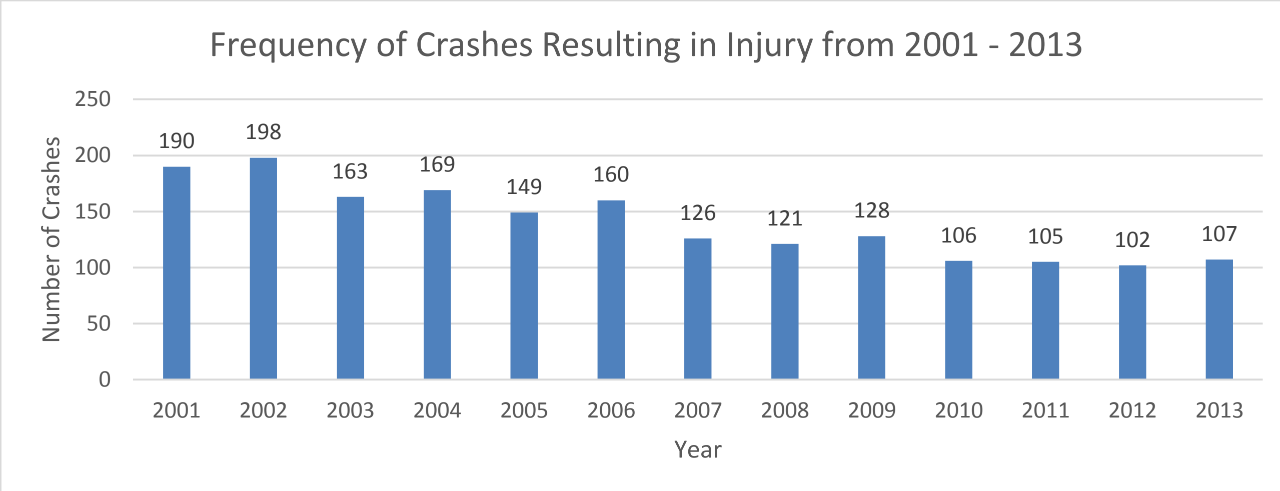
From 2001 to 2013 there were 8466 drivers aged 14 to 15 involved in crashes reported in the Iowa DOT crash database; 835 (9.9%) were excluded due to missing data. The resulting 7631 drivers involved in crashes were included in the analysis. As seen in Figure 3, there was a spike in crashes from 2003 to 2004, followed by a decline, which is consistent with national trends (Insurance Institute for Highway Safety, 2015). The spike in crashes from 2001 – 2002 and 2002 -2003 could be attributed to changes in reporting of data. However, over the last 3 years, 2011 to 2013, the number of crashes leveled off. The average number of crashes per year was 651.

Figure 3: Frequency of Crashes for 14 & 15 year old Drivers in Iowa from 2001 - 2013



Of the crashes that occurred from 2001 to 2013, 22% (n = 1824) resulted in injury. As seen in Figure 4, there has also been a small yet steady decline in the number of crashes resulting in injury from 2001 – 2013. As was true with the overall crash data, the number of crashes resulting in injury began to level off from 2010 - 2013. The mean number of crashes resulting in injury from across the entire study period was 140.

Figure 4: Frequency of Injury Crashes for 14 & 15 year old Drivers in Iowa from 2001 - 2013



Distribution of Crashes by Rurality

Half of all crashes in the dataset occurred in an urban area (n = 4327, 51%), while 7% occurred in a suburban area, 29% in a town and 13% in a remote rural area. This is consistent with the trend that Iowa's population lives primarily in urban areas (State Data Center). For crashes that resulted in injury, a similar trend is seen with 45% of all crashes occurring in urban areas, followed by 33% occurring in towns, 17% in remote rural areas and 6% in suburban areas. When looking at both driver and crash characteristics, trends are consistent across rurality

Table 3, shows the crash rates per 1,000 14 and 15 year old teens and rate ratios by rurality for all crashes and crashes that resulted in injury. Results show, for all crashes, that as the level of rurality increases, rates of crash also increase. Remote rural crashes have the highest crash rate ratio (RR = 1.15, 95% CI: 1.08, 1.22), relative to urban crashes. When looking only at crashes that result in injury, the same trend is seen. As rurality increases, rates increase. Again, remote rural has the highest rate ratios (RR = 1.64, 95% CI: 1.51, 1.77). This result indicates that the increase in crash incidence is disproportionally injury causing.

Table 3: Rates and Rate Ratios for all crashes and crashes that result in injury for young teen drivers

	Rate of All Crashes				Rate of Crashes Resulting in Injury			
	Number of crashes 2001 - 2013	Population of 14 – 15 year olds in Iowa	Rate per 1000 teens	Rate Ratio (95%)	Number of crashes 2001 - 2013	Population of 14 – 15 year olds in Iowa	Rate per 1000 teens	Rate Ratio (95%)
State Total	8466	1,089,605	7.77	_____	1824	1,089,605	1.67	_____
UIC Categories								
Urban	4327	584,224	7.41	REF.	813	584,224	1.39	REF.
Suburban	568	74,322	7.64	1.03 (0.94,1.12)	110	74,322	1.48	1.06 (0.86,1.26)
Town	2442	298,299	8.19	1.11 (1.06,1.16)	598	298,299	2.00	1.44 (1.33,1.55)
Remote Rural	1129	132,760	8.50	1.15 (1.08,1.22)	303	132,760	2.28	1.64 (1.51,1.77)

Population Level Crash and Driver Characteristics

A summary of driver and crash characteristics is presented in Table 4 & Table 5. Overall, males were involved in 52% of crashes and females in 48%. Fifteen year olds were overrepresented in this sample (n = 6887, 81%), compared to fourteen year old drivers (n = 1579, 19%). In the majority of crashes in which seat belt use was known, drivers wore their seatbelt properly, 95% of the time. However, occupant protection was missing in more than half of the reports.

The majority of crashes did not result in injury (n = 6642, 78%). However, of those who were injured, 8% suffered a fatal or incapacitating injury. In the majority of crashes, the teen driver made an error (n = 6109, 77%). The most common teen errors were: loss of control (22%), failure-to-yield-right-of-way (18%), improper action (15%) and speeding (13%). Passengers were present in the vehicle in 10% of all crashes (n = 845). Of the crashes that occurred with passengers, half had one teen passenger in the vehicle (n = 417, 49%) and 19% occurred with multiple teen passengers. When a passenger was present, 64% of crashes resulted in injury. All driver characteristic variables, except for gender, were found to meet criteria for inclusion in multivariable models (p < 0.20).

Table 4: Descriptive statistics for driver characteristics & associations with UIC classifications with Chi-square statistics

Variable		Total	Urban n (%)	Suburban n (%)	Town n (%)	Remote Rural n (%)	Chi square	
							Chi square	p-value
Driver Age								
	14 years old	1579 (19%)	765 (18%)	112 (20%)	472 (19%)	230 (20%)	6.06	0.12
	15 years old	6887 (81%)	3562 (82%)	456 (80%)	1970 (81%)	899 (80%)		
		N/A						
Driver Gender								
	Female	4012 (48%)	2053 (48%)	260 (46%)	1181 (49%)	518 (46%)	2.70	0.44
	Male	4425 (52%)	2252 (52%)	307 (54%)	1256 (51%)	610 (54%)		
	Missing	29 (0.3% of crashes)						
Injury								
	Fatal/ Incapacitating	145 (2%)	58 (1%)	6 (1%)	57 (2%)	24 (2%)	56.08	<.0001
	Non-incapacitating /Possible	1679 (20%)	755 (18%)	104 (18%)	541 (22%)	279 (25%)		
	No Injury	6642 (78%)	3514 (81%)	458 (81%)	1844 (76%)	826 (73%)		
	Missing	N/A						
Occupant Protection								
	None Used	237 (4%)	96 (3%)	13 (4%)	91 (6%)	37 (5%)	30.88	0.0021
	Should & Lap Belt	5305 (95%)	2859 (96%)	353 (95%)	1455 (93%)	638 (93%)		
	Lap belt	24 (0.4%)	11 (0.4%)	1 (0.3%)	7 (0.5%)	5 (1%)		

Table 4: Continued

Shoulder belt	20 (0.4%)	6 (0.2%)	3 (1%)	6 (0.4%)	5 (1%)		
Other	9 (0.2%)	3 (0.1%)	1 (0.3%)	4 (0.3%)	1 (0.2%)		
Missing	2871 (51% of crashes)						
Driver Contributing Circumstance							
No error	1824 (23%)	956 (24%)	125 (23%)	490 (21%)	253 (24%)	82.25	<.0001
FTYROW	1395 (18%)	707 (18%)	115 (21%)	402 (18%)	171 (16%)		
Improper Action	1214 (15%)	682 (17%)	66 (12%)	320 (14%)	146 (14%)		
Failure to obey traffic signals	296 (4%)	182 (5%)	25 (5%)	70 (3%)	19 (2%)		
Speeding	1021 (13%)	488 (12%)	72 (13%)	314 (14%)	147 (14%)		
Lost Control	1718 (22%)	806 (20%)	112 (21%)	527 (23%)	273 (25%)		
Other	465 (6%)	195 (5%)	29 (5%)	171 (7%)	70 (7%)		
Missing	533 (7% of crashes)						
Passenger Presence							
No passengers	7491 (89%)	3886 (91%)	516 (92%)	2115 (88%)	974 (88%)	26.42	0.0017
One teen passenger only	417 (5%)	183 (4%)	25 (4%)	149 (6%)	60 (5%)		
Multiple teen passengers only	157 (2%)	67 (2%)	12 (2%)	46 (2%)	32 (3%)		
At least one adult passenger (regardless of other passengers)	271 (3%)	136 (3%)	11 (2%)	85 (4%)	39 (4%)		
Missing	103 (2% of crashes)						

Half of crashes occurred in the evening (n= 4392, 52%) and the majority of crashes occurred on a weekday (n = 7029, 83%). The majority of crashes involved multiple vehicles (n = 5886, 70%), over half (58%) occurred when the weather was clear and over 68% occurred when the road surface was dry. The majority of crashes were collisions (n = 5749, 69%). Of the crashes that resulted in collisions, there were two main types: angle crashes (n = 2601, 31%) and rear-end crashes (n = 2180, 26%). All crash characteristic variables, except for weather, met criteria for inclusion in multivariable models ($p < 0.20$).

Table 5: Descriptive statistics for crash characteristics & associations with UIC classifications with Chi-square statistics

Variable		Total n (%)	Urban n (%)	Suburban n (%)	Town n (%)	Remote Rural n (%)	Chi-square	
							Chi-square	p-value
Day of Week								
	Weekday	7029 (83%)	3535 (82%)	482 (85%)	2049 (84%)	963 (85%)	12.26	0.0066
	Weekend	1437 (17%)	792 (18%)	86 (15%)	393 (16%)	166 (15%)		
	Missing	N/A						
Time of Day								
	Morning	1837 (22%)	918 (21%)	105 (18%)	547 (22%)	267 (24%)	59.15	<.0001
	Afternoon	1717 (20%)	998 (23%)	128 (23%)	414 (17%)	177 (16%)		
	Evening	4392 (52%)	2143 (50%)	300 (53%)	1331 (55%)	618 (55%)		
	Night	500 (6%)	262 (6%)	35 (6%)	141 (6%)	62 (5%)		
	Missing	22 (0.24% of crashes)						
Manner of Collision								
	Non-collision	2566 (31%)	1086 (26%)	176 (31%)	873 (36%)	431 (39%)	145.45	<.0001
	Head-on	199 (2%)	101 (2%)	17 (3%)	61 (3%)	20 (2%)		
	Rear-end	2180 (26%)	1263 (30%)	118 (21%)	542 (23%)	257 (23%)		
	Angle	2601 (31%)	1361 (32%)	200 (36%)	723 (30%)	317 (28%)		
	Sideswipe	769 (9%)	431 (10%)	49 (9%)	200 (8%)	89 (8%)		
	Missing	151 (2% of crashes)						

Table 5: Continued

Vehicle Number							
Single Vehicle	2580 (30%)	1086 (25%)	178 (31%)	886 (36%)	430 (38%)	128.97	<.0001
Multiple Vehicle	5886 (70%)	3241 (75%)	390 (69%)	1556 (64%)	699 (62%)		
Missing	N/A						
Weather							
Clear	4745 (58%)	2454 (58%)	324 (58%)	1323 (56%)	644 (58%)	3.40	0.33
Not Clear	3494 (42%)	1763 (42%)	230 (42%)	1039 (44%)	462 (42%)		
Missing	241 (3% of crashes)						
Road Surface Condition							
Dry	5588 (68%)	2990 (71%)	379 (68%)	1505 (64%)	714 (64%)	42.56	<.0001
Not Dry	2661 (32%)	1229 (29%)	178 (32%)	857 (36%)	397 (36%)		
Missing	217 (3% of crashes)						

Crash and Driver Risk Factors

No significant difference in odds of injury exists between 14 and 15 year old drivers. When a female was driving, crashes were 31% less likely to result in injury (OR = 0.69, 95% CI: 0.61, 0.78). Crashes where the teen driver lost control were 40% more likely to result in injury (OR = 1.40, 95% CI: 1.11, 1.75) compared to those with other contributing circumstances. Presence of a passenger was found to be highly statistically significant in both the unadjusted and adjusted models. The highest odds of injury occurred when multiple passengers were present. The presence of multiple teen passengers in the vehicle increased the odds of having a crash that resulted in injury 10.73 times, compared to no passengers being present (95% CI: 7.10, 16.22). The odds of having a crash resulting in injury when at least one adult passenger (regardless of other passengers) was present was 7.22 times higher than having no passengers present (95% CI: 5.44, 9.59). Although having one passenger was more frequent than having multiple passengers the odds of a crash resulting in injury were lower, although still significantly increased (OR = 4.88, 95% CI: 3.88, 6.14).

Weekends had a higher odds of injury crashes in the unadjusted model but were no longer significant in the adjusted model (OR = 1.022, 95% CI: 0.88, 1.19). Time of day and road surface condition were not statistically significant predictors of injury in the unadjusted or the adjusted models. Compared with single vehicle collisions, all other manners of collisions had significantly or nearly significantly lower odds of injury. For example, head-on collisions had 32% lower odds of resulting in an injury than single vehicle collisions (95% CI: 0.46, 0.99). Remote rural crashes had 33% higher odds of resulting in injury compared to other UIC groups (95% CI: 1.11, 1.59).

A Hosmer-Lemeshow goodness-of-fit test indicated evidence of poor fit ($x^2 = 14.90$, p = 0.061). This suggests that there are unmeasured variables that are not in the model that may explain the outcome. However, the c statistic, (c = 0.774), indicated acceptable discrimination between observations at the different levels of outcome.

Table 6: Univariable and Multivariable Model

			Univariable Analysis		Multivariable Model	
Variable		Injury n(%)	OR	95% CI	OR	95% CI
Driver Age						
	14 years old	376 (21%)	REF.		REF.	
	15 years old	1448 (79%)	0.85	(0.75, 0.97)	1.02	(0.87, 1.19)
Driver Gender						
	Female	975 (54%)	REF.		REF.	
	Male	843 (46%)	0.73	(0.66, 0.81)	0.68	(0.60, 0.77)

Table 6: Continued

Occupant Protection						
	None Used	140 (10%)	REF.		*	
	Should & Lap Belt	1309 (89%)	0.23	(0.17, 0.30)		
	Lap belt	9 (0.3%)	0.42	(0.18, 0.99)		
	Shoulder belt	11 (1%)	0.85	(0.34, 2.12)		
	Other	2 (0.1%)	0.19	(0.04, 0.97)		
Driver Contributing Circumstance						
	No error	282 (16%)	REF.		REF.	
	FTYROW	185 (11%)	0.84	(0.69, 1.02)	0.87	(0.69, 1.10)
	Improper Action	152 (9%)	0.78	(0.63, 0.97)	0.88	(0.69, 1.12)
	Failure to obey traffic signals	60 (3%)	1.39	(1.02, 1.89)	1.34	(0.94, 1.91)
	Speeding	308 (18%)	2.36	(1.96, 2.84)	1.22	(0.96, 1.56)
	Lost Control	662 (38%)	3.43	(2.92, 4.02)	1.42	(1.13, 1.79)
	Other	105 (6%)	1.60	(1.24, 2.05)	0.84	(0.62, 1.15)
Passenger Presence						
	No passengers	1199 (69%)	REF.		REF.	
	One teen passenger only	250 (14%)	7.86	(6.40, 9.65)	4.88	(3.88, 6.14)
	Multiple teen passengers only	122 (7%)	18.29	(12.50, 26.77)	10.73	(7.10, 16.22)
	At least one adult passenger (regardless of other passengers)	165 (10%)	8.17	(6.35, 10.51)	7.22	(5.44, 9.59)
Day of Week						
	Weekday	1476 (81%)	REF.		REF.	
	Weekend	348 (19%)	1.20	(1.05, 1.37)	0.88	(0.74, 1.04)

Table 6: Continued

Time of Day					
Morning	407 (22%)	REF.		REF.	
Afternoon	345 (19%)	0.88	(0.75, 1.04)	0.82	(0.67, 0.99)
Evening	924 (51%)	0.94	(0.82, 1.07)	0.87	(0.75, 1.02)
Night	137 (8%)	1.33	(1.06, 1.66)	0.79	(0.60, 1.05)
Manner of Collision					
Non-collision	1061 (59%)	REF.		REF.	
Head-on	153(3%)	0.52	(0.37, 0.71)	0.68	(0.46, 0.99)
Rear-end	233 (13%)	0.17	(0.15, 0.20)	0.25	(0.20, 0.30)
Angle	376 (21%)	0.24	(0.21, 0.27)	0.32	(0.26, 0.41)
Sideswipe	75 (4%)	0.15	(0.12, 0.19)	0.24	(0.18, 0.32)
Vehicle Number					
Single Vehicle	1063 (58%)	REF.		*	
Multiple Vehicle	761 (42%)	0.21	(0.19, 0.24)		
UIC Groups					
Urban	813 (45%)	REF.		REF.	
Suburban	110 (6%)	1.04	(0.83, 1.29)	0.99	(0.77, 1.28)
Town	598 (33%)	1.40	(1.24, 1.58)	1.13	(0.98, 1.30)
Remote Rural	303 (17%)	1.59	(1.36, 1.85)	1.33	(1.11, 1.59)
Weather					
Clear	1053 (59%)	REF.		*	
Not Clear	742 (41%)	0.95	(0.85, 1.05)		
Road Surface Condition					
Dry	1180 (66%)	REF.		REF.	
Not Dry	178 (34%)	1.13	(1.01, 1.26)	0.87	(0.76, 0.99)

DISCUSSION

This study examined crash rates as well as crash and driver characteristics associated with crash-related injuries for young teens driving in urban, suburban, town and remote rural areas. For every 1,000 young teen drivers age fourteen to fifteen, nearly 8 were involved in a crash statewide from 2001 - 2013. Of those teens in a crash, 2 out of every 1,000 suffered an injury. Overall crash rates as well as rates of crash that resulted in injury were higher for crashes that occurred on suburban, town and remote rural roads compared with urban areas. Remote rural areas had the highest rate of crash per population. These results are consistent with previous studies, one of which found that the average annual crash rate for drivers age 10 – 15 on remote rural roads was 3.59 times higher than the rate for teens in urban areas (Peek-Asa C. C., 2010).

When comparing crash rates and risk of crash for young teen drivers to older teen drivers, there is a distinct difference. One study found that risk of crash significantly decreased with increasing rurality for drivers age 17 - 24 (Chen H. Y., 2009). Another study found that for older teens, age 16 – 18, non-urban areas had lower rates of crash (Peek-Asa C. C., 2010). On explanation for increased crash rates and risk in urban areas is that the high vehicle density in urban areas could contribute to the increase in multiple vehicle crashes (Lord, 2005). Although the majority of young teen drivers are involved in multiple vehicle crashes, a higher proportion of crashes may be occurring on more rural roads. This is most likely due to increased exposure driving on rural roads for general commute, recreation or having residence in a rural area. The design of rural roads could also contribute to higher risks of crash especially for inexperienced young teen drivers (Zwerling A. P.-A.-W., 2006; Peek-Asa C. Z., 2004).

After adjusting for multiple characteristics, it was found that the characteristics with the strongest association with injury were single vehicle collisions, crashes that occurred on rural roads, crashes were the driver lost control and crashes were multiple teen passengers were present. The findings on rurality are consistent with existing literature suggesting that rural roads pose increased risk for teens (Muelleman, 1996; Maio, 1992). Loss of control contributed to 22% of crashes overall and was a statistically significant risk factor for injury in the adjusted model. This indicates that young teen drivers may not have the experience or knowledge in order to maintain control in different driving situations, specifically on rural roads where road design varies and speeds are increased. Speeding occurred in 13% of crashes, was a statistically significant risk factor for injury in in the unadjusted model, and was a nearly significant risk factor in the adjusted model. Having increased odds of crash resulting in injury due to speeding is consistent with existing literature that states that teens are at a higher risk of crash and are more likely to participate in risky driving behavior like speeding (Williams A. F., 2007). Both loss of control and speeding speak to a lack of maturity and experience driving. These drivers, when put on rural roads, are at an increased risk of injury due to the fact that both speeding and loss of control have the potential to have a fatal result. Nearly a quarter of crashes occurred due to no error on the part of the teen. This indicates that although the teen was not at fault, their immaturity in the driving environment could have led to not being able to avoid a crash.

The presence of a passenger was associated with higher odds of a crash resulting in injury and was highly statistically significant. Odds of injury crash increased significantly with the presence of multiple teen passengers. When at least one adult passenger (regardless of other passengers) was present, the odds were lower than when multiple teen passengers were present; however, the odds were still higher than having a single teen passenger. This relationship between increasing risk of injury crash with increasing the number of passengers is consistent with existing literature (Chen L. B., 2000).

Iowa's graduated driver's license (GDL) program allows teens to drive independently starting at the age of fourteen if they have obtained a school permit. Restrictions with a school permit are similar to that of an intermediate license, which can be obtained at 16 years old. Driving between 5 a.m. and 10 p.m., using electronic devices, carrying more than one other teen passenger and driving off of the most direct route to school or a school-related event are the main restrictions placed on young teen drivers. However, passenger restrictions, for teens with a school permit or an intermediate license, is one of the main restrictions of GDL. This restriction is based on extensive a priori knowledge and data that has consistently proven that having a passenger present is extremely dangerous and increases the risk of crash exponentially (Williams A. F., 2007; Williams A. F., 2007; Williams A. F., 2002). Nevertheless, some young teen drivers are not adhering passenger restrictions, allowing for multiple passengers in the vehicle. Even those who are adhering to the guideline of having only one teen passenger in the vehicle are still at risk, indicating a need for change in the GDL policy.

The findings of this study highlight important characteristics of young teen drivers who crash. These results have great implications for driving policy for this specific age range. In the United States, nine states currently allow young teen drivers, age fourteen, to obtain their learners permit. The majority of these nine states permit supervised driving but in Iowa independent driving is permitted with a school permit. Results indicate that driving independently and especially driving with a passenger are both dangerous for these young teen drivers. Ergo, this speaks to changes needed to policies that permit driving at such a young age.

Limitations

A major limitation of this study is that the data are only available for young teens who crash. The base population at risk, which is teens in this age range who drive, is not known, and thus for rate calculations we used population estimates. With population rates we were able to calculate a population level incidence, but we are not able to examine crash risk factors. Thus, we focused our study on the risk of injury given a crash, which allowed us to use injured drivers as the outcome and all of those in a crash as the exposed population. When determining rurality, the location of the crash is used. This is a limitation due to the fact that the teen may not live in a rural area and might only be driving on a rural road. Therefore crashes rates cannot be looked at as the rate of crashes for teens who are from rural areas, only the public health burden of crashes that occur on rural roads can be investigated. Using UIC groups also presents a limitation due to the fact that county level measures of rurality does not account for micro areas within counties, therefore there may be more urban or rural areas of a county that is not captured in the Urban Influence Code. When estimating the rates of crashes, there is not detailed information about which teens drive and how much. Therefore, population rates will be used which could be biased because rural teens may driver more than urban teens, resulting in more conservative estimates. Another limitation of this study would be generalizability. Due to the fact that this study looks at a small percentage of the driving population it may not be generalizable to other age groups. However, due to the fact that there is little to no research on this vulnerable population this limitation is minimal and holds little significant as to the importance of this study.

CONCLUSION

As the number of young teen drivers increases in Iowa, the need for research for this specific population simultaneously increases. Young teen drivers are extremely vulnerable due to their lack of maturity, limited experience and exposure to high speed dangerous roads yet, they are an understudied population. Results from this study demonstrate the dangerous circumstances that young teen drivers face, especially when driving on rural roads. This study clearly demonstrates the need for more restrictions on the number of passengers and the development of prevention methods to make young teen drivers safer, specifically on rural roads.

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