ORIGINAL ARTICLE

Fatal motor vehicle crashes in rural and urban areas: decomposing rates into contributing factors

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Objectives: Motor vehicle crash fatality rates have been consistently higher in rural areas than in urban areas. However, the explanations for these differences are less clear. In this study the decomposition method was used to explore the factors associated with increased fatal crash involvement rates in rural communities.

Design: Using national databases, the fatal crash incidence density was decomposed into the product of three factors: the injury fatality rate, the crash injury rate, and the crash incidence density.

Results: As expected, the fatal crash incidence density was more than two times higher in rural than in urban areas. This was driven primarily by the injury fatality rate, which was almost three times higher in rural areas.

Conclusions: Further research should examine the relative roles of crash severity and the timely receipt of definitive medical care after a crash.

Motor vehicle injury fatality rates have been consistently higher in rural areas than in urban areas.[1–19] This has been true for the elderly[2] as well as for children.[4 15] According to the 2001 National Highway Traffic Safety Administration (NHTSA) traffic safety statistics, 61% of traffic fatalities occurred in rural areas even though rural areas account for only 40% of the vehicle miles traveled and 21% of the population.[19] Rural motor vehicle injury fatality rates have been higher than urban rates in several state and local studies,[6–17] as well as in studies of different countries.[18 20–23] Although motor vehicle injury fatality rates have declined over the last 20 years, rural rates continue to exceed urban rates.[19]

Researchers have proposed a wide range of potential explanations for the differences in motor vehicle injury fatality rates between rural and urban areas: rural drivers may drive more miles than their urban counterparts[3 5]; they may be less likely to take safety measures, such as wearing seat belts or properly restraining children[3–5 8]; there may be differing patterns of alcohol use[8 24]; rural roads may be less safe than urban roads[8 24–28]; rural vehicles may be less safe than urban vehicles[5 8]; rural crashes may be more severe than urban crashes (because of differing speed limits or road conditions)[3 8 10 19 24 29]; rural crash victims may not receive medical attention as quickly as urban crash victims; and the quality of the medical response may not be as good.[7 8 10–13 18 30 31]

The decomposition method offers one approach to tease apart the different components of crash risk and their contribution to rural and urban crashes. The decomposition method has been used by health economists to assess the relative importance of the many risk factors leading to increased medical expenses.[32] However, this method has only recently been introduced into the area of injury epidemiology to identify the contribution of risk factors associated with motor vehicle crashes.[33–35] Here, we use the decomposition method to explore the factors associated with increased fatal crash involvement rates in rural compared with urban communities.

DESIGN

Disaggregation of the fatal crash involvement rate

Figure 1 shows that the fatal crash incidence density rate can be viewed as the product of three factors: the injury fatality rate, the crash injury rate, and the crash incidence density. Thus the risk of being in a fatal crash (A) is the product of the risk of dying when a crash involving injury occurs (B), the risk of injury given a crash (C), and the risk of crash per miles driven (D). We compare rural to urban fatal crash incidence densities as a ratio:

$$\frac{\text{A rural}}{\text{A urban}} = \frac{\text{B rural}}{\text{B urban}} \times \frac{\text{C rural}}{\text{C urban}} \times \frac{\text{D rural}}{\text{D urban}}$$

The ratios of B, C, and D indicate the relative importance of the injury fatality rate, the crash injury rate, and the crash incidence density respectively in explaining the ratio of the rural-to-urban fatal crash incidence densities. This approach is described in more detail elsewhere.[33 34]

Data sources

Data on the number of fatal crashes in the study come from the Fatality Analysis Reporting System (FARS) maintained by the NHTSA. The FARS data derive from a census of fatal traffic crashes within the 50 states, the District of Columbia, and Puerto Rico. Fatal crashes listed in the FARS database involve motor vehicles traveling on roadways customarily open to the public and involving the death of an occupant of a vehicle or a non-motorist within 30 days of the crash. The crash fatality data in this study come from the 2001 FARS data file.

Data on the total number of crashes and of crashes with injuries in the United States derive from the National Automotive Sampling System's General Estimates System (GES), a nationally representative probability sample of all police reported crashes in the United States. To be included in the GES sample, the crash must involve at least one motor vehicle traveling on a public road that leads to property damage, injury, or death. Only crashes that generate a police report are included. Here, we use data from the 2001 GES database.[19]

Abbreviations: FARS, Fatality Analysis Reporting System; GES, General Estimates System; HPMS, Highway Performance Monitoring System; NHTS, National Household Travel Survey; NHTSA, National Highway Traffic Safety Administration

Fatal crash incidence density (A)		Injury fatality rate (B)		Crash injury rate (C)		Crash incidence density (D)
$\frac{\text{\# fatal crashes}}{\text{\# vehicle miles traveled}}$	=	$\frac{\text{\# fatal crashes}}{\text{\# crashes with injuries}}$	×	$\frac{\text{\# crashes with injuries}}{\text{\# all crashes}}$	×	$\frac{\text{\# all crashes}}{\text{\# vehicle miles traveled}}$

Figure 1 Disaggregation of the fatal crash incidence density into component parts.

We used two sources for data on vehicle miles traveled. The Highway Performance Monitoring System (HPMS) of the Federal Highway Administration provides the best source of data on vehicle miles traveled. The HPMS is based upon observations of traffic patterns at more than 4000 sites chosen to represent the United States as a whole.[36] Although this database has the advantage of being based on observations rather than self reports, it does not provide stratified data based on the age and sex of the driver.

In order to decompose rates by age and sex, a measure of individual exposure was needed. For these stratified analyses, data on vehicle miles traveled are derived from the National Household Travel Survey (NHTS). The NHTS utilizes computer assisted telephone interviews of about 26 000 households to obtain self reported estimates of vehicle miles traveled from a representative, national sample. They have been collected from April 2001 through May 2002. The person interview response rate was 63.4%.[37]

Rural *v* urban

The different databases used for this analysis employ different measures of rurality. The FARS and GES databases determine the rurality of the crash site geographically based on the rurality of the police jurisdiction in which the crash occurs. Towns with populations of less than 25 000 were considered rural. The HPMS measures the rurality of the vehicle miles traveled by the type of roadways on which they are driven. In contrast, the NHTS provides no data on where miles were driven. Rather, it determines rurality based on the zip code of residence reported by the sample of drivers. Towns with populations of less than 50 000 were considered rural.

Severity

In order to assess the possibility of confounding by the severity of the crash, we used the damage to the vehicle as a measure of the severity of the crash. Vehicular damage was considered severe if the police report specified the damage as disabling or if the police report noted that the vehicle was towed due to damage. Otherwise, damage was not considered severe.

Analysis

We decomposed the ratio of the rural compared to urban fatal crash incidence density into the analogous ratios of the injury fatality rates, the crash injury rates, and the crash incidence densities. This initial decomposition used HPMS location specific vehicle miles traveled and thus was irrespective of age and sex. Then we repeated the decomposition using the NHTS person specific vehicle miles traveled to stratify for age and sex. Finally, we repeated the decomposition restricting the analysis to crashes that caused severe vehicular damage.

Table 2 Comparison of the fatal crash incidence density, injury fatality rate, crash injury rate, and crash incidence density between rural and urban

Ratios of rural/urban	Fatal crash incidence density	Injury fatality rate	Crash injury rate	Crash incidence density
For all crashes*	2.23	2.99	1.12	0.67
For crashes with severe vehicular damage†	1.62	1.92	1.06	0.8

*Data on fatalities from FARS.
†Data on fatalities from GES.

RESULTS

Overall disaggregation

Table 1 summarizes the data used in this study: the number of fatal crashes, the number of crashes with injuries, the total number of crashes, and the number of miles driven. As expected, the fatal crash incidence density, the injury fatality rate, and the crash injury rate were all higher in rural than in urban areas, but the crash incidence density was lower in rural than in urban areas.

Table 2 compares the fatal crash involvement rate and its three components (the injury fatality rate, the crash injury rate, and the crash incidence density) in rural and in urban areas. The top row presents the primary results of this paper. As expected, the fatal crash incidence density was more than two times higher in rural than in urban areas. The injury fatality rate was almost three times higher in rural than urban areas. And the crash injury rate was higher in rural areas as well. However, the crash incidence density was lower in rural than in urban areas.

Stratified analysis by age and sex

Using self reported vehicle miles traveled, we were able to carry out an analysis stratified by age and sex. Table 3 compares the fatal crash incidence density and its three components (injury fatality rate, crash injury rate, and crash

Table 1 Fatal crash incidence density, injury fatality rate, crash injury rate, and crash incidence density

Rurality	No of fatal crashes	No of crashes with injuries	No of total crashes	No of miles driven	Fatal crash incidence density (A)	Injury fatality rate (B)	Crash injury rate (C)	Crash incidence density (D)
Rural	31 602	1 203 015	3 231 766	1105 083 000 000*	2.86	26.27	372.25	2.92
Urban	21 447	2 438 720	7 355 459	1676 379 000 000*	1.28	8.79	331.55	4.39
Total	53 049	3 641 735	10 587 225	2781 462 000 000*	1.91	14.567	343.97	3.81

*Based on observations by the HPMS of the Federal Highway Administration.
(A) (Number of fatal crashes/number of miles) per 100 million miles driven.
(B) (Number of fatal crashes/number of crashes with injury) per 1000 crashes with injuries.
(C) (Number of crashes with injury/number of all crashes) per 1000 crashes.
(D) (Number of all crashes/number of miles) per million miles driven.

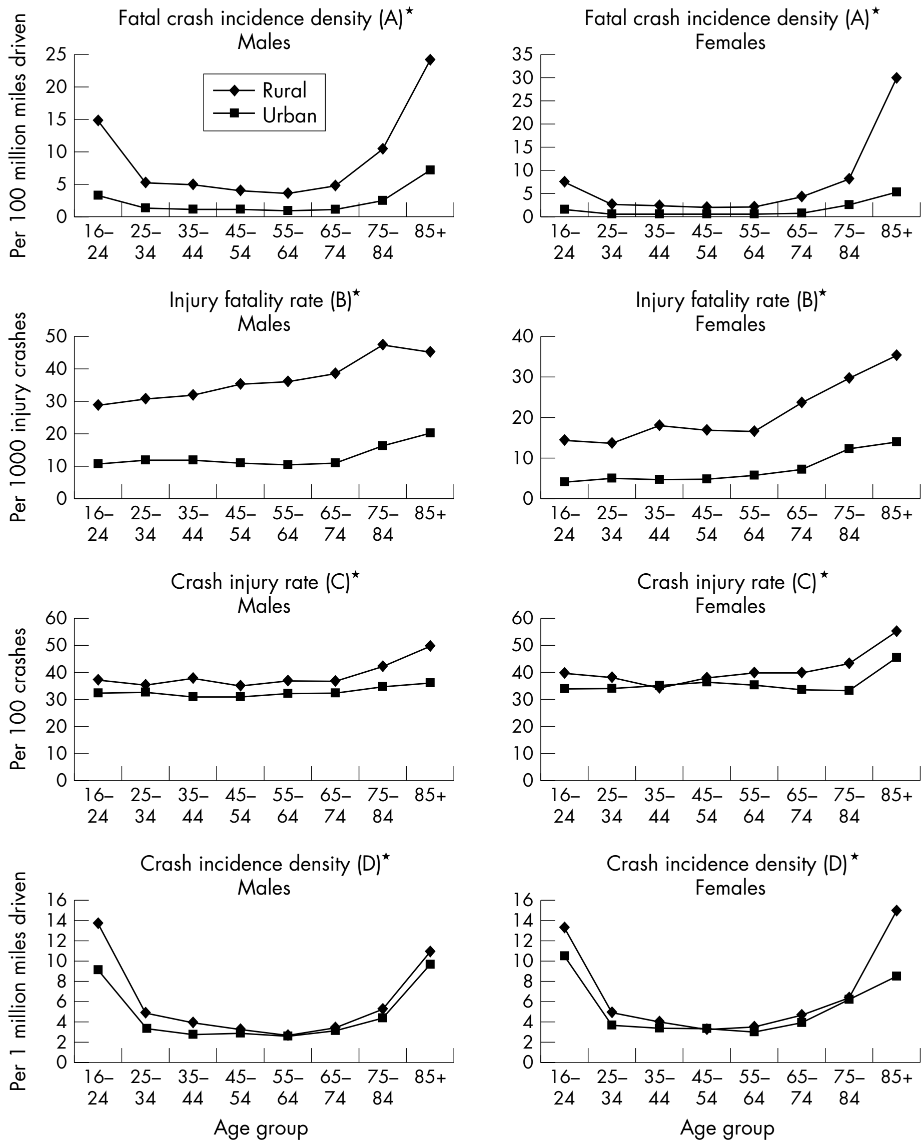

Figure 2 Fatal crash incidence density, injury fatality rate, crash injury rate, and crash incidence density by age and sex. *Capital letters refer to definitions in fig 1.

incidence density) in rural areas with urban areas for each stratum. For all ages and both sexes, the rural fatal crash incidence density was between 3.1 and 4.8 times that of the urban rate. For all ages and both sexes, this difference resulted primarily from the increased injury fatality rate in rural areas compared to urban areas. The ratios of rural compared to urban rates were remarkably stable in spite of changes in the rates with age and sex, as demonstrated in fig 2. For example, fig 2 demonstrates that the fatal crash incidence density was higher for the youngest and oldest drivers among urban and rural men and women. The injury fatality rate increased with age among rural and urban men and women. The crash incidence density increased markedly for the youngest and oldest drivers among rural and urban men and women.

Analysis restricted to crashes with severe damage

The bottom row of table 2 compares the ratios of rural to urban rates restricted to crashes that resulted in severe damage to the vehicle. This analysis was undertaken to assess the potential impact of confounding by severity. Table 2 shows that the pattern of results among the severe crashes was similar to that among all crashes. In both analyses, the rural/urban ratio of the injury fatality rate was largest (about three for all crashes and about two for severe crashes). This difference in magnitude suggested some confounding by severity.

DISCUSSION

Consistent with other research comparing crashes in rural and urban environments, we found that fatal crash incidence density is more than two times higher on rural than urban roads.[1–19] We found that the injury fatality rate contributed more to the difference in fatal crash incidence density than either crash injury rate or crash incidence density. Since the fatal crash incidence density and the crash incidence density both correct for vehicle miles traveled (driving exposure), the increased risk for fatality on a rural road is linked with factors associated with the crash and after the crash rather than with driving exposure.

Many different types of risk factors may contribute to the increased injury fatality rate on rural roads. If crashes or crash injuries are more severe on rural roads, then fatalities will be more common. Increased crash severity on rural roads

Table 3 Comparison of the fatal crash incidence density, injury fatality rate, crash injury rate, and crash incidence density between rural and urban drivers by age and sex

	Rural/urban ratios			
	Fatal crash incidence density	Injury fatality rate	Crash injury rate	Crash incidence density
Male				
16–24	4.66	2.75	1.14	1.49
25–34	3.96	2.59	1.09	1.41
35–44	4.79	2.73	1.22	1.44
45–54	3.88	3.23	1.12	1.07
55–64	4.05	3.47	1.14	1.02
65–74	4.26	3.54	1.12	1.07
75–84	4.29	2.91	1.23	1.20
85+	3.35	2.21	1.38	1.10
Female				
16–24	4.67	3.16	1.17	1.27
25–34	3.98	2.64	1.11	1.35
35–44	4.18	3.74	0.98	1.14
45–54	3.49	3.39	1.05	0.98
55–64	3.49	2.78	1.11	1.13
65–74	4.53	3.27	1.17	1.18
75–84	3.11	2.38	1.30	1.01
85+	5.40	2.51	1.22	1.76

may occur because crash characteristics are different on rural than urban roads. For example, rural drivers may be more likely to have head-on crashes because traffic streams are not divided. Rural drivers may also be more likely to have single vehicle collisions with stationary objects because roadsides do not have guardrails. These two types of crashes have an increased likelihood of producing fatal injuries than rear-end or broadside collisions.[3 8 10 19 24 29]

To assess the impact of crash severity on the increased injury fatality rate, we reanalyzed the GES 2001 database restricting the analysis to those crashes that caused severe damage to the vehicle-vehicles that had disabling (severe) damage noted in the police report or had to be towed from the scene (due to damage). Other vehicles were considered to have minor damage. When we limited our analysis to the severe crashes, we found the same overall pattern of the decomposition in rural compared to urban crashes. These results indicate some confounding by severity but also show that the injury fatality rate has the largest relative contribution to increased rural injury fatality rates for both overall and severe crashes. Thus, some of the increased fatality in rural areas may be due to increased injury severity within severe damage crashes, but this finding strongly suggests that survival given an injury crash, both overall and with severe damage to the vehicle, is poorer in rural crashes.

Driver characteristics may also contribute to increased injury severity. Rural drivers are less likely to use seat belts[4 5 8] and may drive older cars that are less likely to have airbags.[36] Rural drivers may also drive at greater speeds,[3 5 8 37 38] and may be more likely to be drinking during hours of high crash risk.[8 24] Another possible explanation would be an increased proportion of older drivers in rural areas, who have increased fragility and are more likely to die in a crash.[35] Our data show that older drivers had lower driving exposure than all other age groups, but a higher crash fatality incidence density. Older drivers also had a higher crash involvement rate when compared to all age groups except those aged 16–24. However, the injury fatality rate was the strongest contributor to fatal crash involvement for all age and gender groups, which discounts age trends as a strong predictor of increased fatal crash involvement.

Another important component of increased injury fatality is access to medical care. Rural crashes occur in more remote areas, where both the response of the emergency medical services and access to definitive care may be delayed.[7 8 10 13 18 30 39] Many rural crashes are not witnessed, and therefore efforts to summon help may be significantly delayed. When help is summoned, response time may be longer because of distances to the crash. In addition, many rural areas are served by volunteer ambulance drivers,[40] who sometimes must leave their jobs, get to the ambulance, and respond to a remote crash. Because trauma centers are not concentrated in rural areas, the transport time to definitive care is increased. Emergency medical service providers must make important decisions between lengthy transport to a trauma center or faster transport to a local hospital, and if these decisions are not made quickly and correctly, then definitive care may be delayed.[41 42]

Crash incidence density was slightly higher on urban than on rural roads, although road design of many rural roads is thought to enhance crash risk. These risk factors include fewer traffic control devices (including many intersections with no controls at all), non-graded curves, traffic streams that are not separated, and less traffic enforcement. It is possible that the absence of these protective measures contribute more to increased crash severity than to increased crash involvement. This hypothesis has not been formally studied.

Our results should be interpreted cautiously because of several limitations in applying the decomposition method to compare rural and urban roads. First, the FARS may slightly underestimate the number of fatal crashes by not counting off-the-road fatalities and deaths that occur more than 30 days after the crash. This underestimation will only affect these results if the under-reporting is different for rural and urban roads. Second, the GES excludes crashes that were not reported to the police, which tend to be less severe and less damaging crashes. Again, this will only influence our comparisons if the ratio of fatal to non-fatal crashes in rural compared to urban crashes is differentially affected by non-reporting.

Third, in order to apply the decomposition model stratified by age and gender, we had to use self reported exposure miles. This application creates some error in the model because the exposure miles by age and gender category are based on residence rather than actual areas driven. However, previous research has indicated that the majority of miles driven correspond with residence, and that this difference is similar for rural and urban areas.[5 30 43] Furthermore, we have no reason to expect differential representation in rural and urban areas across age and gender strata. Thus, we believe

Key points

- Motor vehicle fatal crash incidence densities have been consistently higher in rural areas than in urban areas.
- The decomposition method allows us to represent the fatal crash incidence density as the product of three factors: the injury fatality rate, the crash injury rates, and the crash incidence density.
- The crash fatality incidence density was more than two times higher in rural than in urban areas.
- This excess appears to be driven by the injury fatality rates which were almost three times higher in rural areas.

that this analysis provides an accurate comparison of the rate contributions in age and gender strata.

Fourth, our study—like all ecologic studies—is vulnerable to uncontrolled confounders.[44] In particular, the variables available in our data sets may not have been able to fully control for confounding by severity of the crash.

Our findings suggest that secondary and tertiary prevention, which reduce severity and consequences from injury once a crash has occurred, are important areas for intervention in rural communities. Interventions to reduce speed and increase seat belt usage on rural roads may help to reduce disparity in fatal crash involvement rates. Efforts to better understand effective emergency medical service and trauma care delivery in rural areas is also a priority to decrease rural crash fatalities. Further research should examine the relative role of crash severity and receipt of definitive medical care following a crash. As suggested in a recent General Accounting Office report,[45] this information will help further refine and prioritize research and intervention activities.

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