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Incidence and characteristics of school bus crashes and injuries

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ABSTRACT

Objective: Studies of school bus crashes have focused on the biomechanics of catastrophic collisions, with very few examining crash incidence.
Methods: Crashes in the state of Iowa were examined from January 2002 through December 2005. School bus crashes were identified through the Iowa Crash Data, a comprehensive database of all reported crashes in the State of Iowa. School bus mileage data were provided by the Iowa Department of Education. School bus crash, fatality, and injury rates were calculated and differences in crash and injury characteristics between school buses and other vehicles were examined.
Results: The school bus crash, fatality and non-fatal injury rates were 320.7, 0.4 and 13.6 per 100 million bus miles travelled, respectively. School bus crash fatality and injury rates were 3.5 and 5.4 times lower than overall all vehicle crash fatality and injury rates, respectively. Drivers of other vehicles were more likely to have caused the crash than the bus driver ($P < 0.001$).
Conclusions: School buses experience low crash rates, and the majority of crashes do not lead to injury. Buses are among the safest forms of road transportation, and efforts to educate drivers of other vehicles may help reduce crashes with buses.

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1. Introduction

Every day, school buses transport more than 23 million children to and from school, with additional transportation for field trips and school-related events (Hinch et al., 2002). The majority of school bus crash studies have examined the biomechanics of school bus occupant injuries to increase crashworthiness and reduce fatal and severe injuries, with a particular focus on design features inside the bus (Hinch et al., 2002; Transportation Research Board [TRB], 2002). These studies have focused primarily on frontal collisions and rollover crashes, which are the most likely to result in fatality or severe injury (Lapner et al., 2003). However, these types of crashes are relatively rare (Lapner et al., 2003).

Only a few published studies have examined the number of school bus crashes and injuries. The findings vary widely depending on the source of information and study population included, ranging from an estimated annual number of crash related school bus occupant injuries of 5500 based on crash data (TRB, 2002) to more than 17,000 injuries that included all mechanisms of injury on school buses using medical sources (McGeehan et al., 2006). Miller and Spicer (1998) identified that an average of about 32 children are killed and another 8600 injured yearly in school bus-related events, leading to medical costs of $21,481,000 (1993 dollars).

The major impediment to the epidemiological examination of school bus crash incidence is the difficulty in finding complete data for both the numerator (crashes and injuries) and the denominator (e.g., school bus miles traveled) (TRB, 2002; National Transportation Safety Board, 1999). The National Transportation Safety Board concluded that national data on bus-related injuries is incomplete. Some states do not report bus crashes, some do not differentiate school buses from other vehicles, and some do not use uniform reporting standards (National Transportation Safety Board, 1999). School bus mileage data are also difficult to obtain because school buses are coded inconsistently, and school bus transportation mileage must often be estimated from the hours of travel (TRB, 2002; National Transportation Safety Board, 1999). Such estimates will underestimate mileage by excluding travel during trips that are not associated with transportation to and from school, such as field trips (TRB, 2002; National Transportation Safety Board, 1999;

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Committee on Injury, Violence, and Poison Prevention and Council on School Health, 2007).

Understanding the characteristics of school bus crashes and injuries and the associated risk factors is important and will help parents, students, and officials make more informed decisions regarding safety in school travel. In this study, we estimate the incidence rates of school bus crashes, fatalities, and injuries for the state of Iowa and identify risk factors and characteristics of school bus crashes and injuries. This study is possible because the Iowa Department of Transportation obtains complete police investigative reports for all school bus crashes and the Iowa Department of Education keeps detailed records of school bus mileage (Iowa Department of Education, 2007).

2. Methods and materials

2.1. Study data and population

Study data were from the Iowa Crash Data (ICD) maintained by the Iowa Department of Transportation, Office of Driver Services. The ICD includes all investigating police officers' reports of motor vehicle crashes, as well as drivers' reports for any crash not investigated by law enforcement, regardless of severity. The database includes separate, hierarchically linked data files that describe the characteristics and circumstances of the crashes, the vehicles, the drivers, and the injuries.

Crashes from 2002 through 2005 that involved a school bus registered in Iowa were identified through a unique vehicle code for school buses. The Iowa Department of Transportation defines a school bus as a vehicle for transporting students to and from schools or other locations for school-related activities. The vehicle classification in this study was based on the investigating police officer's assessment at the scene.

A total of 749 school bus crashes were identified between 1 January 2002 and 31 December 2005. Of these, 725 crashes involved one Iowa school bus, five crashes involved two Iowa school buses, and 19 crashes involved school buses from other states. These 19 were excluded from further analysis because we had no information on their mileage. Therefore, a total of 730 crashes that involved 735 Iowa school buses were included, and these crashes involved 733 other vehicles.

2.2. Study variables

Variables included in this study were crash characteristics, environmental factors, and driver characteristics. *Crash characteristics* included crash year, season, day, time, and whether the crash involved a collision with another vehicle. *Environmental factors* included lighting, road type (non-intersection and intersection), speed limit ($\leq$25 mph, 30–50 mph, and $\geq$55 mph), and weather conditions (clear, cloudy, fog, rain, snow, and severe winds). *Driver characteristics* included driver age, gender, severity of injury, driver actions listed as a contributing circumstance to the crash (i.e., losing control of vehicle, failing to yield, inattention, driving too fast, or following too closely), and whether or not the driver was charged with a violation.

Injuries were categorized in the ICD as fatal, incapacitating (major), not incapacitating (minor), possible (complaint of pain with no visible injury), and unknown injury. For this study, we excluded possible and unknown injuries and categorized injuries as fatal, major, or minor.

School bus mileage, an exposure variable, was used for the denominator when calculating school bus crash, fatality and non-fatal injury rates. The school bus mileage was provided by the Annual Mileage Driven by Iowa Public School Buses, a document published by the Iowa Department of Education (Iowa Department of Education, 2007). School bus mileage included miles traveled by yellow buses and other vehicles that were used for transporting students to and from schools or other locations for school-related activities. School buses were distinguished by type, and were either classified as being a large school bus (those seating more than 15 occupants) or a small school bus (those seating 15 occupants or less).

Other vehicles in this study were defined as any vehicle other than a school bus. These included passenger cars, light trucks, large trucks, and motorcycles.

2.3. Analysis

School bus crash rates per 100 million miles driven were calculated as the number of school bus crashes during each of the 2002 through 2005 academic school years (July 1st to June 30th) divided by total mileage driven by Iowa school buses during the same academic year. School bus fatality and non-fatal injury rates per 100 million miles driven were calculated as the number of school bus occupants' deaths or injuries for each of the 2002 and 2005 academic school years divided by total mileage driven by Iowa school buses during the same academic year. Comparison data for fatality and non-fatal injury rates for all vehicles were obtained from the Department of Motor Vehicles, Office of Driver Services. All of the analyses were conducted in SAS. The differences in crash and injury characteristics between school buses and other vehicles were examined using Chi-square tests.

3. Results

3.1. School bus crash and injury rates

The average school bus crash rate for the 4-year study period was 320.7 per 100 million bus miles traveled, with similar crash rates across the 4 study years (Table 1). The school bus fatality and non-fatal injury rates were 0.4 and 13.6 per 100 million miles traveled, respectively. The majority of bus occupants were not killed or injured even when crashes occurred: only 0.1 out of every 1000 school bus occupants were killed and only 7.6 of every 1000 school bus occupants were injured.

School bus occupants were less likely to be injured than other parties involved in the crashes. A total of 10 fatal and 139 non-fatal injuries were reported in the 730 school bus crashes (Table 2). Only one fatality occurred to a school bus occupant, and this was a passenger. Of the remaining fatalities, six occurred to occupants of other vehicles and three to pedestrians or pedal cyclists. Of the 139 non-fatal school bus injuries, 15 (10.8%) were to school bus drivers, 50 (36.0%) were to school bus passengers, 69 (49.6%) were to other vehicle occupants, and 5 (3.6%) were to pedestrians or pedal cyclists. School bus drivers accounted for 15 out of 65, or 23.1%, of the total number of injuries sustained by school bus occupants.

Just over 12% of non-fatal school bus injuries were severe, compared with 27.5% of injuries to other vehicle occupants. A total of 8530 occupants were in the school bus in the fatal and injury crashes (not shown in tables).

3.2. Characteristics of school bus crashes

The majority of the school bus crashes occurred during a weekday (97%), involved a collision with another vehicle or a fixed object (97.8%), and had no injuries reported (87.7%) (Table 3). School bus crashes were also most common on roads with a speed limit under 50 mph (75.2%) and during school drop-off and pick-up periods, with 40.7% of crashes occurring from 6:00 a.m. to 8:50 a.m. and 36.7% from 2:00 p.m. to 4:50 p.m., respectively. School bus crashes

Table 1
School bus crash rates, by year.

	Crashes (N)	Fatal crashes (N)	Injury crashes[a] (N)	Bus occupant fatalities[b] (N)	Bus occupant injuries[c] (N)	Total miles bus driven[d]	Crash rate per 100 million miles driven[e]	Bus fatality rate per 100 million miles driven[f]	All vehicle fatality rate in Iowa, 2006	Bus injury rate per 100 million miles driven[g]	All vehicle injury rate in Iowa, 2006
Total	730	10	80	1	31	227,615,635	320.7	0.4	1.38	13.6	74.0
School year											
January 2002–June 2002	77	1	7	0	4	28,735,252	268.0	0		13.9	
July 2002–June 2003	184	1	23	1	9	56,680,475	324.6	1.8		15.9	
July 2003–June 2004	192	2	20	0	8	56,604,738	339.2	0		14.1	
July 2004–June 2005	182	5	22	0	9	57,216,944	318.1	0		15.7	
July 2005–December 2005	95	1	8	0	1	28,378,226	334.8	0		3.5	

[a] Fatal crashes are excluded.
[b] Includes crashes involving deaths of school bus drivers or school bus passengers.
[c] Includes crashes involving injuries among school bus drivers or school bus passengers. Fatal cases are excluded.
[d] The miles bus driven are based on data published by the Iowa Department of Education on annual mileage driven by Iowa public school buses.
[e] Crash rates per 100 million miles driven were calculated as the number of school bus crashes divided by total miles school bus driven.
[f] Fatal crash rate per 100 million miles driven were calculated as the number of crashes involving deaths of school bus drivers or passengers divided by total miles school bus driven.
[g] Injury crash rate per 100 million miles driven were calculated as the number of crashes involving injuries among school bus drivers or passengers divided by total miles school bus driven.

Table 2
Fatalities and non-fatal injuries in school bus crashes, Iowa, 2002–2005.

	Fatalities, *N* (%)	Injuries, *N* (%)
School bus drivers	0(0)	15(10.8)
School bus passengers	1(10)	50(36.0)
Other vehicles	6(60)	69(49.6)
Pedestrian and bicycles	3(30)	5(3.6)
Total	10(100)	139(100)

were less common in the summer (8.6%) compared to other seasons. Of 730 recorded school bus crashes, 39 (5.3%) involved a single school bus. The main factors associated with a single bus crash were a collision with a fixed object (e.g., bridge, poles, tree, ditch, mailbox, etc.) (33.3%), collision with a non-motorist (18.0%), overturn/rollover (15.4%), and collision with an animal (7.7%). The only crash characteristics associated with injury were increased speed limit and the absence of a collision with another vehicle, in which a pedestrian or bicyclist was most likely to be injured. Of 39 single bus crashes, three involved fatal injuries with two to pedestrians and one to a pedal cyclist.

3.3. Driver and vehicle characteristics

Compared to school bus drivers, a significantly higher proportion of young non-school bus drivers were involved in school bus crashes, with 16% of non-school bus drivers under the age of 17 and 15.7% between ages of 18 and 25 (Table 4). Although male drivers comprised a significantly higher proportion for both types of vehicles, a higher proportion of male school bus drivers were involved in the school bus crashes compared to drivers of other vehicles. School bus drivers were charged in 16.2% of school bus crashes. Drivers for other vehicles, however, accounted for about twice as many charges as that of bus drivers and were charged for 32.1% of the school bus crashes ($P < .0001$).

The bus driver was coded as having no improper action in 49.3% of the crashes and no specified contributing cause in another 22.3%, for a total of 71.6% of crashes in which the bus driver had no recorded contributing action (Table 4). In contrast, drivers of other vehicles had no recorded contributing action in only 58.4% of crashes. Other vehicles were more likely than bus drivers to violate signals, lose control, drive recklessly, fail to yield, drive too fast, and follow too close. Contributing actions associated with environmental conditions were more frequent among bus drivers. Following too closely and speeding were especially common among drivers of other vehicles who were under 18 years of age (not shown in tables).

We have further compared school bus crashes per certified school bus driver to all cause crashes per licensed 15–18-year-old drivers, which occurred during the weekdays when school was in session between the times 6:00–8:50 a.m. (drop-off) and 2:00–4:50 p.m. (pick-up) (Table 5). The findings showed that crash rates of 15–18-year-old drivers were almost twofold higher when compared to those of bus drivers in the four study years.

3.4. School bus crash configurations

The most common type of crash configuration between one bus and one car ($N = 651$) occurred when the other vehicle rear-ended the bus (21.2%) (Table 6). It was far less common for the bus to rear-end a car (6.9%). Crashes during a turn accounted for a total of 23.3% of crashes, and crashes were much more likely when the bus was turning (16.4% of all crashes) than the other vehicle (6.9% of all crashes). Broadside crashes accounted for 17.4% of crashes, with the other vehicle more likely to broadside the bus than vice versa.

Table 3
Characteristics of school bus crashes and those crashes involving injuries.

Characteristics	Number of crashes, *N* (%)	Number of crashes involving injuries, *N*	Proportions of crashes involving injuries (%)	*P*[a]
Total	730	90	12.3	
Season				0.1393
Winter (December–February)	230 (31.5)	20	8.7	
Spring (March–May)	199 (27.3)	31	15.6	
Summer (June–August)	63 (8.6)	10	15.9	
Fall (September–November)	238 (32.6)	29	12.2	
Weekday				0.6390
Yes	708 (97.0)	88	12.4	
No	22 (3.0)	2	9.1	
Time				0.7135
6:00 a.m.–8:50 a.m.	297 (40.7)	41	13.8	
8:50 a.m.–2:00 p.m.	114 (15.6)	15	13.2	
2:00 p.m.–4:50 p.m.	268 (36.7)	30	11.2	
4:50 p.m.–6:00 a.m.	48 (6.6)	4	8.3	
Unknown	3 (0.4)	0	0.0	
Type of school bus				0.1763
Large school bus (seats >15)	671 (91.9)	86	12.8	
Small school bus (seats 9–15)	59 (8.1)	4	6.8	
Collision with another vehicle or a fixed object				<.0001
Yes	714 (97.8)	81	11.3	
No	15 (2.1)	8	53.3	
Unknown	1 (0.1)	1	100	
Road type				0.2171
Non-intersection	349 (47.8)	39	11.2	
Intersection	368 (50.4)	51	13.9	
Unknown	13 (1.8)	0	0.0	
Speed limit				<.0001
≤25 mph	320 (43.8)	22	6.9	
30–50 mph	229 (31.4)	29	12.7	
≥55 mph	141 (19.3)	38	27.0	
Unknown	40 (5.5)	1	2.5	
Weather				0.8450
Clear	363 (49.7)	47	13.0	
Partly cloudy/cloudy	219 (30.0)	27	12.3	
Fog/smoke/mist	24 (3.3)	2	8.3	
Rain	40 (5.5)	6	15.0	
Sleet/hail/freezing rain/snow	58 (8.0)	7	12.1	
Severe winds/blowing sand/soil/dirt/snow	10 (1.4)	0	0.0	
Unknown	16 (2.2)	1	6.3	

[a] Chi-square *P* values.

The most common types of catastrophic crashes were reported very infrequently, which include head-on collisions (3.4% of crashes) and over-turning (0.5% of crashes).

4. Discussion

School buses are a very safe form of transportation, with crash fatality and injury rates far lower for school buses than for other vehicles. We found that the school bus fatality rate was 0.4 per 100 million miles traveled. In comparison, the overall crash fatality rate for all vehicles in Iowa in 2006 was 1.38 per 100 million miles traveled, which is 3.5 times higher. Iowa's crash injury rate of 74.0 per 100 million miles traveled is 5.4 times higher than the school bus crash injury rate of 13.6 per 100 million miles traveled. In school bus crashes, fatalities and injuries occur much more frequently to other parties involved in the crash than to the occupants of the school bus. Pedestrians and bicyclists are particularly vulnerable.

School bus crashes were most frequent during weekday mornings and afternoons, which account for the majority of driving exposure as buses travel to and from school. Our findings also showed that compared to crash rates of 15–18-year-old drivers during weekday morning drop-off and afternoon pick-up time, school bus drivers had much lower crash rates. Although not all licensed 15–18-year-old drivers are actually driving to/from school, nor do all the certified school bus drivers actually drive each day, our findings indicate that young drivers have much higher crash rates and that riding to and from school by school bus is a safer option. McGeehan et al. (2006) suggested that there could be an increased risk for school bus crashes during weekend trips or off-campus field trips. We were not able to examine this trend because exposure data was not available by day and time.

This study was conducted in a predominantly rural state. We were unable to examine the influence of rurality on bus crashes because mileage by roadway type was not available. Overall crash rates are higher on rural roads (Zwerling et al., 2005; Peek-Asa et al., 2004), and bus exposure is higher because rural children often travel further distances to get to their school than urban children. The only study to date that has examined bus-related injuries by area found that pedestrians have an increased risk for school bus and tram injuries on rural, country roads (Ungar et al., 2002).

Drivers of other vehicles were more likely than the bus driver to contribute or cause the crash. Similar trends were found in previous studies on light vehicle–heavy vehicle crashes and injury outcomes, indicating that light vehicle drivers are most often at fault in the crashes (Blower, 1998; Stuster, 1999; Hanowski et al., 2007). Based

Table 4
Driver and vehicle actions in school bus crashes.

	School bus		Other vehicle		*P*-Value[a]
	N	%	*N*	%	
Total	735		733		
Driver age					<.0001
1–17	1	0.1	117	16.0	
18–25	17	2.3	115	15.7	
26–45	172	23.4	210	28.7	
46–65	381	51.8	150	20.5	
65+	151	20.5	53	7.2	
Unknown	13	1.8	88	12.0	
Driver gender					<.0001
Male	462	62.9	363	49.5	
Female	260	35.4	284	38.7	
Unknown	13	1.8	86	11.7	
Driver charged					<0.001
Yes	119	16.2	235	32.1	
No	581	79.1	464	63.3	
Unknown	35	4.8	34	4.6	
Repair cost					<.0001
≤1000	522	71.0	210	28.7	
1000–5000	180	24.5	458	62.5	
5000–10000	21	2.9	53	7.2	
> 10000	12	1.6	12	1.6	
Driver contributing circumstances					<.0001
Signal violation	5	0.7	25	3.4	
Lost control or driving recklessly	53	7.2	67	9.1	
Failure to yield	98	13.3	104	14.2	
Inattention	10	1.4	9	1.2	
Environmental	21	2.9	13	1.8	
Driving too fast	10	1.4	56	7.6	
Followed too close	12	1.6	31	4.2	
Not specified	164	22.3	152	20.7	
No improper action	362	49.3	276	37.7	

[a] Chi-square *P* values.

Table 5
Crashes during school driving times (weekdays 6:00–8:50 a.m. and 2:00–4:50 p.m.).

Year	Crashes involving certified school bus drivers			Crashes involving licensed 15–18-year-old drivers		
	Crashes (*N*)	Drivers (*N*)	Rate/1000 person[a]	Crashes (*N*)	Drivers (*N*)	Rate/1000 person[b]
Total	558	36,917	15.1	14,905	546,219	27.3
2002	112	9,354	12.0	3,927	136,078	28.9
2003	145	9,147	15.9	3,790	136,739	27.7
2004	159	9,687	16.4	3,644	137,149	26.6
2005	142	8,729	16.3	3,544	136,253	26.0

[a] Rate was calculated as the number of crashes divided by the number certified school bus drivers, then time 1000.
[b] Rate was calculated as the number of crashes divided by the number licensed 15–18 drivers, then time 1000.

Table 6
Distribution of collision type for crashes with one bus and one vehicle, *N* = 651.

Collision type	Description	Number of crashes	
		N	%
Car rear-end bus	Front of car impacts rear of bus	138	21.2
Bus turning	Bus was turning right or left	107	16.4
Car broadside bus	Front of car impacts side of bus, both vehicles moving straight	67	10.3
Bus broadside car	Front of bus impacts side of car, both vehicles moving straight	46	7.1
Bus rear-end car	Front of bus impacts rear of car	45	6.9
Car turning	Car was turning right or left	45	6.9
Head-on	Frontal impact for both bus and vehicle	22	3.4
Both turning	Both bus and car turn	15	2.3
Passing	Bus passing car (*N* = 3); car passing bus (*N* = 4)	7	1.1
Unknown	Actions are not known	16	2.5
Other	Other situations	143	22.0

on the age distribution of drivers involved in crashes with a school bus, student drivers appear to be at greater risk. Common crash configurations involved a vehicle rear-ending the bus or hitting the bus while it was turning, and the most common contributing causes to these crashes were failing to yield, losing control/driving recklessly, driving too fast, and following too closely. These are the same driving errors commonly identified for young drivers (McKnight and McKnight, 2000, 2003).

These findings have implications for reducing bus crashes and suggest that school bus safety programs need to include drivers of other vehicles. Education for drivers of other vehicles in school zones, particularly young drivers, may be helpful in reducing school bus crashes as well as all cause crashes. For example, education about safe driving around buses could be incorporated into driver's education programs. Such information could also be routinely sent home as school handouts for both student and parent drivers. These findings also have implications for school district busing policies, which should consider safety as a factor in policy decisions. Since crash injury rates were far lower for bus occupants than passenger vehicle occupants, policies that encourage the use of buses for events such as field trips may increase safety. Safety should also be considered when deciding on boundaries for bus services for transport to and from school.

This study had several limitations. Mileage data was available for overall school bus travel and was not available among exposure categories. For example, although we show that large buses (15 or more seats) comprised 91.9% of crashes, these buses likely have the majority of miles traveled. Small buses may have greater risks per mile traveled. Another limitation of the study is that number of school bus occupants was based on the police report at the crash scene, which may not be accurate. Finally, our findings were based on the data from one state, which could limit the generalizability of the results.

5. Conclusion

School buses are among the safest forms of road transportation. Efforts to educate drivers of other vehicles may help reduce crashes. The increased safety of school bus transportation over other vehicles should be a factor in making school transportation policies. Educating children and their parents about safe driving around school buses may be beneficial to the safety of all children traveling to and from school.

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