Spatial Demography of Head Injury Incidence and Crashed Motor Vehicle Type in Illinois

Prepared for

Illinois Department of Public Health (IDPH) and Illinois Department of Transportation (IDOT)

by

Mickey Edwards, MPA, PhD

University of Illinois at Springfield

HEdwa4@uis.edu

Introduction

The danger posed to human bodies in the event of a motor vehicle crash is caused by the rapid transfer of energy resulting from the deceleration of multiple objects attempting to simultaneously occupy the same physical space. Increased vehicular mass and speed increase the amount of energy transferred, but the time taken to decelerate to zero remains relatively constant, leading to more severe injuries. On our roadways, the dramatic variation in geometry and heft of our motor vehicle fleet leads to lopsided distributions and transfers of deadly and injurious energy. By focusing on redistributing energy away from human bodies and slowing down (increasing the time to decelerate to zero) that transfer of energy, deaths and injuries may be reduced or prevented.

A reasonable question to ask, considering the motivating factor for many to own and drive large vehicles, is whether occupants of large vehicles are safer relative to those in other vehicle types. Outreach by crash and safety experts, similar to **Image 1**, certainly helps to show that idea. However, the safety reality is more complicated, especially from the road user's perspective. Large vehicles can be more deadly for pedestrians and cyclists, especially among children (Edwards and Leonard, 2022). But what about the occupants of larger vehicles? Are some types of vehicles safer than others? And who is most at risk for injury, especially the most serious types like severe head injuries?

This exploratory study conducts a high-level examination of seven years of linked crash and hospital data throughout the state of Illinois. As discussed in the Related Research section of this paper, studying motor vehicle crash outcomes can be a complicated journey. Most research in this field focuses on a particular type of crash (car versus car, truck versus car, truck versus fixed object, etc.) and a particular type of road user (senior drivers, child passengers, rear seat passengers, female drivers, etc.). With certain notable exceptions (teen drivers, rural pickup truck crashes), this study largely makes no distinction between crash scenarios or road user types. Rather, we investigate crash outcomes of all occupants by vehicle type in the aggregate to gain a better understanding of the general risk posed when involved in a crash. Succeeding studies may gain a more narrow focus as a result of the findings presented here.

Image 1: IIHS social media post encouraging parents to provide large vehicles for their teenage drivers to protect them during a crash

Related research

In collisions, tall and heavy vehicles are more aggressive against occupants of other vehicles while providing more protection for their own occupants, leading to more injurious outcomes for occupants of smaller vehicles relative to larger ones (Monfort and Nolan, 2019; Karaca-Mandic and Lee, 2013; Ulfarsson and Mannering, 2004). This mismatch in injury outcomes based on varying vehicle characteristics is frequently referred to as incompatibility (Teoh and Nolan, 2012). If two or more vehicles vary significantly enough to disproportionately cause injury to the occupants of one type over the other to be deemed incompatible with one another. Though occupants of larger vehicles may be less safe relative to occupants of passenger cars in crashes involving fixed objects because of the increased rigidity of large vehicles (Ulfarsson and Mannering, 2004). The goal of this stream of research is to better understand how vehicles may become more compatible with one another, thus reducing death and injury.

Many other important, but difficult to measure, factors can lead to injury and death resulting from a crash. Apart from vehicle type classification, the manner in which a vehicle is manufactured can contribute to crash outcomes. For example, pickup truck-based body-on-frame construction may lead to worse crash outcomes for both the occupants and others relative to the more modern unibody design (Wenzel and Ross, 2005). From a safety perspective, progress has been made by some vehicle types for all vehicle occupants. From the late 1980s and early 1990s to 2013 and later, the threat of death posed to drivers of passenger cars by striking SUVs decreased by a factor of five (Monfort and Nolan, 2019). However, pickup trucks have made essentially no progress over the same period. Pickup trucks are particularly injurious for occupants of passenger cars, with trucks being 158% more likely to kill drivers, relative to crashes between passenger cars (Ibid).

To control for human characteristics that may contribute to crashes and crash outcomes, many studies include metrics of personal attributes of those involved as related factors. Potentially contributory personal characteristics studied span much of the diversity of humanity. Driver age (Forman et al., 2019), teenaged drivers and senior drivers are of particular interest (Rahman et al., 2021; Hamann et al., 2020; Kim et al., 2020; Cox and Cicchino, 2021; Rapoport et al., 2021; Classen et al., 2021), gender (Atwood et al., 2023; Brumbelow and Jermakian, 2021; Linder and Svensson, 2019; Ulfarsson and Mannering, 2004), and body type (Forman et al., 2019) are just a few examples

Research statement

Much of the research into vehicle type and injury outcomes disaggregate crash types and those involved into neatly defined categories and studies those that meet their classification criteria. This disaggregation is done to control for the complexity of contributing crash factors and scenarios. While that variety of study is certainly good and valuable, here, rather than analyzing a single occupant or crash type among predetermined criteria, this study aims to investigate general overall crash outcomes. When making vehicle purchase decisions, it seems unlikely that the consumer has in mind just one crash type for which they base their vehicle type. More likely, a general sense of safety is associated with vehicle size and type that influences specific purchases.

Whether or not this general sense of safety associated with vehicle size and type is reflected in the crash data is just what this study aims to understand. Unless otherwise stated, the analyses presented here utilize linked statewide Illinois crash and hospital discharge data.

Sources and methods

Crash and hospital data linkage

Funded by a grant from the Illinois Department of Public Health in collaboration with the Illinois Department of Transportation and the University of Illinois at Springfield, Illinois crash and hospital records for the years 2016 through 2022 were successfully linked. The linkage was accomplished using the software LinkSolv – consisting of probabilistic linkage methods developed in the National Highway Traffic Safety Administration's Crash Outcome Data Evaluation System program (McGlincy, 2021). A combination of data fields common to both files were identified as those with the highest success rate of linking the crash and hospital files: county, victim age, crash date, victim date of birth, and victim sex. Geographical tolerances were permitted for nearby counties since the crash may have occurred in a county different from that of the hospital where treatment was received. Crash date tolerance was also permitted one day into the future to allow for the dawning of a new day before a crash victim reaches a hospital.

Cook County, home to Chicago, is where some 40% of the Illinois population resides, effectively making the county a relatively indiscriminate match field – which is a factor controlled for in the LinkSolv software. These linked files are critical in our understanding of the effects of motor vehicles on the lives of the citizens of Illinois. Such an investigation as presented here would not be possible without the successful linkage of the disparate crash and hospital files.

The hospital files include rich (yet not personally identifiable) individual patient data who were admitted under urgent, emergency, and trauma admission types. Individual patient race, ethnicity, sex, and age are included as fields in the hospital files, among many others.

Results

The analysis file consists of 420,169 linked crashes among passenger cars, SUVs, pickup trucks, and vans/minivans. Of these 289,888 (69%) are passenger cars, 79,680 (19%) are SUVs, 25,860 (6.2%) are pickup trucks, and 24,741 (5.9%) are vans/minivans. As this analysis employs only linked crash and hospital data, these figures represent an undercount of the true scale. Still, the share presented in this sampling reflects the true share of population vehicle type.

All injuries among all vehicle occupants

Without regard to seating position, road conditions, or other potential contributing crash factors, **Table 1** shows the distribution of injurious and fatal crashes across vehicle types. While passenger cars represent 69% of linked crashes, occupants of these vehicles are underrepresented in fatal crashes at 61.7% of the total. Within vehicle type, 0.3% of linked crashes among occupants of passenger cars resulted in a fatality – the lowest rate among studied vehicle types. SUVs represent 19% of linked crashes, but their occupants made up 23.4% of fatal crashes. While 0.5% of SUV occupants in a crash were killed – the second highest death rate within vehicle type. Occupants of pickup trucks were twice as likely to be killed when involved in a crash compared to occupants of passenger cars, 0.6% and 0.3%, respectively. And though pickup trucks make up 6.2% of linked crashes, their occupants represent 8.9% of fatalities. Vans and minivans are at parity in terms of occupant representation at 5.9% of both fatal crashes and vehicle type involvement. About 0.4% of van and minivan occupants were killed when involved in a crash, an average rate among vehicle types but elevated relative to the passenger car. Collectively, then, occupants of SUVs, pickup trucks, and vans/minivans are each overrepresented as decedents relative to their shares of crash involvement. While occupants of passenger cars involved in crashes, though still the great majority, are underrepresented as decedents relative to their share of all crashes.

*Table 1: Distribution of injurious and fatal linked crashes by vehicle type (Illinois, 2016-2022)**

			KABCO					
			0	1	2	3	4	Total
Vehicle Type	Passenger	Count	110908	61683	93996	22314	987	289888
		% within Vehicle Type	38.3%	21.3%	32.4%	7.7%	0.3%	100.0%
		% within KABCO	70.0%	68.0%	69.2%	66.7%	61.7%	69.0%
		% of Total	26.4%	14.7%	22.4%	5.3%	0.2%	69.0%
	Pickup	Count	9202	4883	8648	2984	143	25860
		% within Vehicle Type	35.6%	18.9%	33.4%	11.5%	0.6%	100.0%
		% within KABCO	5.8%	5.4%	6.4%	8.9%	8.9%	6.2%
		% of Total	2.2%	1.2%	2.1%	0.7%	0.0%	6.2%
	SUV	Count	29313	18360	25400	6232	375	79680
		% within Vehicle Type	36.8%	23.0%	31.9%	7.8%	0.5%	100.0%
		% within KABCO	18.5%	20.2%	18.7%	18.6%	23.4%	19.0%
		% of Total	7.0%	4.4%	6.0%	1.5%	0.1%	19.0%
	Van/Mini-Van	Count	9021	5836	7845	1944	95	24741
		% within Vehicle Type	36.5%	23.6%	31.7%	7.9%	0.4%	100.0%
		% within KABCO	5.7%	6.4%	5.8%	5.8%	5.9%	5.9%
		% of Total	2.1%	1.4%	1.9%	0.5%	0.0%	5.9%
Total		Count	158444	90762	135889	33474	1600	420169
		% within Vehicle Type	37.7%	21.6%	32.3%	8.0%	0.4%	100.0%
		% within KABCO	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	37.7%	21.6%	32.3%	8.0%	0.4%	100.0%

**K(4): Fatal; A(3): Incapacitating injury; B(2): Non-incapacitating injury; C(1): Injury not evident; O(0): No indication of injury; $p < 0.000$; Pearson Chi-Square = 817; Cramer's V = 0.025*

Head injuries among all vehicle occupants

The potential for lifelong negative consequences of traumatic brain injuries (TBI) is well studied and documented (Carroll et al., 2010; Graham et al., 2021; Howlett, et al., 2022; Brett et al., 2022). Though the hospital data used in this analysis do not explicitly specify nor diagnose a TBI, a reasonable proxy is a sustained head injury rated on the abbreviated injury scale (AIS, 0-6) of two or higher. An AIS of two is considered a moderate injury, with a three-score considered serious, and so on (**Table 2**).

Table 2 shows the relationship between potential TBIs, measured as a hospital-diagnosed abbreviated injury score (AIS) of two or greater (Carroll et al., 2010), and the type of vehicle occupied by the patient during a crash. Relative to analyzing fatal crashes, results get more nuanced with the inclusion of other injuries – moderate or worse head injuries in this case. Despite typically being among the tallest and heaviest vehicles on the road, pickup trucks emerge as most injurious for the heads of its occupants, with 3.7% of crashes resulting in moderate to severe head injury. Vans and minivans appear to be the most protective against moderate or worse head injury for occupants when analyzed in the aggregate, with 2.3% of crashes resulting in such. While passenger car occupants are slightly overrepresented at one percentage point more likely to endure a moderate or worse head injury relative to their crash involvement rate. SUV occupants are slightly underrepresented by two percentage points, the most among vehicle types studied here – suggesting SUVs may be protective against head injury.

A reasonable explanation for these variations may be found in the personal traits of drivers (and maybe passengers) with the predilection to purchase various vehicle types. A motorist who purchases a sports car may have a different appetite for taking risks on the roadway relative to the owner of a min-van, for example. Vehicle construction method variation also undoubtedly plays a role in crash and injury outcomes, since a pickup truck will typically have a more rigid and less energy-absorbing frame (Wenzel and Ross, 2005).

*Table 2: Relationship between head injuries of AIS 2+ and vehicle type (Illinois, 2016-2022)**

			Head AIS 2+		
			0	1	Total
Vehicle Type	Passenger	Count	281691	8197	289888
		% within Vehicle Type	97.2%	2.8%	100.0%
		% within Head 2+	69.0%	70.0%	69.0%
		% of Total	67.0%	2.0%	69.0%
	Pickup	Count	24907	953	25860
		% within Vehicle Type	96.3%	3.7%	100.0%
		% within Head 2+	6.1%	8.1%	6.2%
		% of Total	5.9%	0.2%	6.2%
	SUV	Count	77678	2002	79680
		% within Vehicle Type	97.5%	2.5%	100.0%
		% within Head 2+	19.0%	17.1%	19.0%
		% of Total	18.5%	0.5%	19.0%

Van/Mini-Van	Count	24181	560	24741
	% within Vehicle Type	97.7%	2.3%	100.0%
	% within Head 2+	5.9%	4.8%	5.9%
	% of Total	5.8%	0.1%	5.9%
Total	Count	408457	11712	420169
	% within Vehicle Type	97.2%	2.8%	100.0%
	% within Head 2+	100.0%	100.0%	100.0%
	% of Total	97.2%	2.8%	100.0%

**AIS = abbreviated injury scale; 1: minor injury, 2: moderate injury, 3: serious injury, 4: severe injury, 5: critical injury, 6: maximum/fatal injury; $p < 0.000$; Pearson Chi-Square = 126; Cramer's V = 0.017*

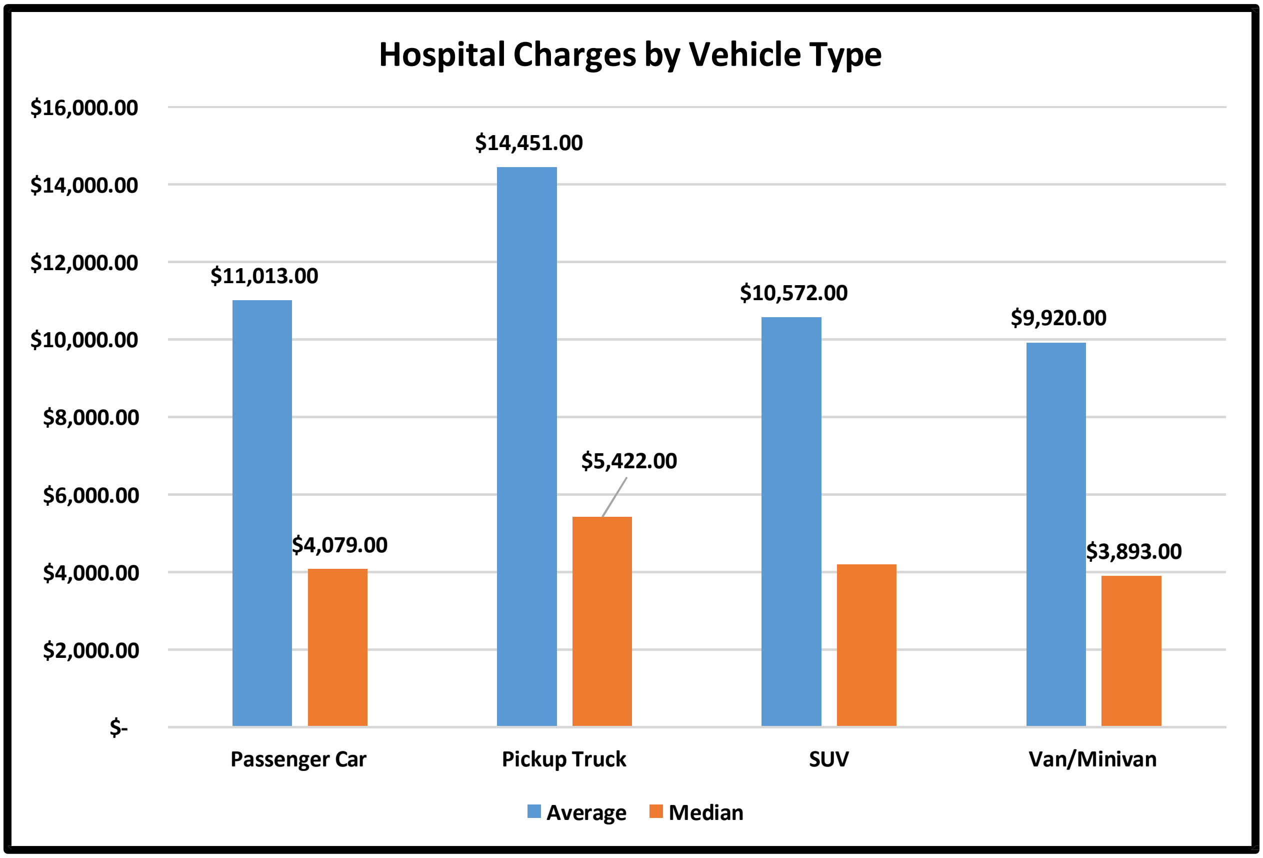
Hospital charges and vehicle types

The seven years of linked crash and hospital data studied here across all vehicle types represent some $6,037,040,120 (an average of $862 million annually) in hospital charges to treat injuries sustained in a motor vehicle crash in Illinois. Those charges translate to an annual average of about 0.008 cents for every single mile travelled throughout the state by all vehicles and by all road users.

Figure 1 communicates the average and median hospital charges by vehicle type for occupants involved in a motor vehicle crash across the seven study years. The substantial differences between average and median charges highlight the large standard deviation found in the data. These substantial standard deviations are caused by a few outlying incidents of very high charges.

Pickup truck occupants had the highest average and median hospital charge of all vehicle types at $14,451 and $5,422, respectively. This economic outcome is perhaps unsurprising given the supporting evidence throughout this paper demonstrating that, in the aggregate, pickup truck occupants also had worse injury outcomes. Once more, passenger car and SUV occupants had similar average and median hospital charges. A greater standard deviation had passenger cars slightly edging out SUVs by about $500 at an average of $11,013. While the difference between medians was just about $100, with SUVs higher at $4,188. Crashed occupants of vans and minivans had the lowest average and median hospital charges at just under $10k and just under $4k, respectively.

*Figure 1: Average and median hospital charges by occupied vehicle type**



**Standard deviations: passenger car = $38k; pickup truck = $48k; SUV = $33k; van/minivan = $32k*

Disproportionately affected road users

The preceding analysis has worked to establish that, in the aggregate, pickup truck occupants typically sustain more severe injuries when in a crash relative to occupants of other vehicle types by various measures. This leads to an important question, who are those most likely to be injured in a pickup truck crash? Generally, they are men. Though males make up 44.2% of those involved in a linked crash, males represent 73% of pickup truck occupants. It is no surprise then that males make up 56.5% of all moderate or worse head injuries and 80.1% of them that occur in a pickup truck.

Table 3 shows that road users who are White are significantly overrepresented as occupants of crashed pickup trucks at 73.9% of incidents despite comprising just 49.2% of all crashes. White road users are also overrepresented as occupants of crashed SUVs and vans/minivans at 53.1% and 54.2% of incidents, respectively. In terms of crashed passenger cars, White occupants are about four percentage points underrepresented. The distribution of vehicle occupants who are Black is just about the inverse of the White experience. At 32.3% of linked patients, road users who are Black occupy 36% of crashed passenger cars – an overrepresentation. Just 12.3% of crashed pickup trucks had a Black occupant, twenty percentage points fewer than their representation in the data. Black occupants of crashed SUVs were underrepresented by about five percentage points, and about seven percentage points in vans/minivans.

Table 3: Distribution of crashed vehicle types by race

			Vehicle Type				
			Passenger	Pickup	SUV	Van/Minivan	Total
Race	American Indian or Alaska Native	Count	1257	76	360	124	1817
		% within Race	69.2%	4.2%	19.8%	6.8%	100.0%
		% within Vehicle Type	0.4%	0.3%	0.5%	0.5%	0.4%
		% of Total	0.3%	0.0%	0.1%	0.0%	0.4%
	Asian	Count	6686	152	2061	689	9588
		% within Race	69.7%	1.6%	21.5%	7.2%	100.0%
		% within Vehicle Type	2.3%	0.6%	2.6%	2.8%	2.3%
		% of Total	1.6%	0.0%	0.5%	0.2%	2.3%
	Black or African American	Count	104463	3190	21935	6244	135832
		% within Race	76.9%	2.3%	16.1%	4.6%	100.0%
		% within Vehicle Type	36.0%	12.3%	27.5%	25.2%	32.3%
		% of Total	24.9%	0.8%	5.2%	1.5%	32.3%
	Declined/Unknown	Count	1435	96	401	132	2064
		% within Race	69.5%	4.7%	19.4%	6.4%	100.0%
		% within Vehicle Type	0.5%	0.4%	0.5%	0.5%	0.5%
		% of Total	0.3%	0.0%	0.1%	0.0%	0.5%
	Native Hawaiian or Other Pacific Islander	Count	1073	72	336	109	1590
		% within Race	67.5%	4.5%	21.1%	6.9%	100.0%
		% within Vehicle Type	0.4%	0.3%	0.4%	0.4%	0.4%
		% of Total	0.3%	0.0%	0.1%	0.0%	0.4%
	Other	Count	40497	2983	11456	3831	58767
		% within Race	68.9%	5.1%	19.5%	6.5%	100.0%
		% within Vehicle Type	14.0%	11.5%	14.4%	15.5%	14.0%
		% of Total	9.6%	0.7%	2.7%	0.9%	14.0%
	Two/More	Count	2607	178	788	201	3774
		% within Race	69.1%	4.7%	20.9%	5.3%	100.0%
		% within Vehicle Type	0.9%	0.7%	1.0%	0.8%	0.9%
		% of Total	0.6%	0.0%	0.2%	0.0%	0.9%
	White	Count	131870	19113	42343	13411	206737

	% within Race	63.8%	9.2%	20.5%	6.5%	100.0%
	% within Vehicle Type	45.5%	73.9%	53.1%	54.2%	49.2%
	% of Total	31.4%	4.5%	10.1%	3.2%	49.2%
Total	Count	289888	25860	79680	24741	420169
	% within Race	69.0%	6.2%	19.0%	5.9%	100.0%
	% within Vehicle Type	100.0%	100.0%	100.0%	100.0%	100.0%
	% of Total	69.0%	6.2%	19.0%	5.9%	100.0%

p < 0.000; Pearson Chi-Square = 10384; Cramer's V = 0.091

Table 4 shows that Hispanic road users are two percentage points more likely to occupy a crashed SUV but about a point less likely to occupy a crashed pickup truck compared to non-Hispanics. And though Hispanic road users represent 14.2% of linked crashes, they are slightly overrepresented in crashed SUVs at 15.5% of incidents. Road users who are non-Hispanic, meanwhile, are slightly overrepresented in crashed pickup trucks and underrepresented in crashed SUVs. However, as demonstrated above in **Table 3**, the "Other" race category represents the third largest racial cohort with nearly 59,000 crashed vehicle occupants. Researchers have shown the "Other" racial category to be disproportionately comprised of Hispanics who do not identify with any of the optional races (Lopez, 2023). In fact, when comparing the results of the "Other" racial category and the Hispanic ethnicity category, the count and share of the distribution across crashed vehicle types are remarkably similar – supporting Lopez's (2023) findings.

Table 4: Distribution of crashed vehicle types by Hispanic ethnicity

			Vehicle Type				
			Passenger	Pickup	SUV	Van/Mini-Van	Total
Ethnicity	Declined/Unknown	Count	3752	321	1128	299	5500
		% within Ethnicity	68.2%	5.8%	20.5%	5.4%	100.0%
		% within Vehicle Type	1.3%	1.2%	1.4%	1.2%	1.3%
		% of Total	0.9%	0.1%	0.3%	0.1%	1.3%
	Hispanic	Count	40412	3228	12356	3809	59805
		% within Ethnicity	67.6%	5.4%	20.7%	6.4%	100.0%
		% within Vehicle Type	13.9%	12.5%	15.5%	15.4%	14.2%
		% of Total	9.6%	0.8%	2.9%	0.9%	14.2%
	Non-Hispanic	Count	245724	22311	66196	20633	354864
		% within Ethnicity	69.2%	6.3%	18.7%	5.8%	100.0%
		% within Vehicle Type	84.8%	86.3%	83.1%	83.4%	84.5%

	% of Total	58.5%	5.3%	15.8%	4.9%	84.5%
Total	Count	289888	25860	79680	24741	420169
	% within Ethnicity	69.0%	6.2%	19.0%	5.9%	100.0%
	% within Vehicle Type	100.0%	100.0%	100.0%	100.0%	100.0%
	% of Total	69.0%	6.2%	19.0%	5.9%	100.0%

$p < 0.000$; Pearson Chi-Square = 232; Cramer's V = 0.017

Teen injuries and vehicle types

Returning to **Image 1** and the assertion that "smaller cars provide less crash protection" for teenage drivers, **Table 5** quantifies the dangers posed to such drivers by vehicle type using our linked Illinois dataset. For our dataset, passenger cars serve as smaller cars relative to the other three categories. **Table 5** shows that non-teen drivers are less likely than teen drivers to sustain a moderate or worse head injury across all studied vehicle types.

Among linked teen drivers (aged 16-19), those in crashed pickup trucks had the greatest likelihood of sustaining a moderate or worse head injury at 5.4% of incidents. Teen drivers in crashed passenger cars and SUVs each had a 3.5% chance of sustaining a similar head injury. Crashed teen drivers of vans/minivans had, by a slim margin, the smallest chance of sustaining a similar head injury at 3.3% of incidents.

Aside from pickup trucks, the remaining three vehicle types are essentially at parity in terms of incidence of head injuries. These findings imply that what is typically among the largest of vehicles on the road – the pickup truck, poses the greatest risk of moderate or worse head injury to teen drivers and occupants. The typical SUV would commonly be considered larger than the typical passenger car, yet **Table 5** shows that no additional protection is provided for teen drivers of SUVs. Vans/minivans measure slightly better, or more protective, than the others, with 3.3% of teen drivers sustaining a moderate or worse head injury. In plain terms, there is no evidence that teenage drivers are safer in larger vehicles. In fact, in the aggregate, the opposite may be true – larger vehicles may be more injurious for teenage drivers.

*Table 5: Share of teen and non-teen head injury of AIS2+ by occupied vehicle type and among all crash scenarios**

Vehicle Type	*Teen Driver*	*Non-Teen Driver*	*All Teens (Drivers & Passengers)*
Passenger Car	3.5%	2.8%	3.7%
Pickup Truck	5.4%	3.6%	5.2%
SUV	3.5%	2.5%	3.7%
Van/Minivan	3.3%	2.3%	3.4%

**AIS = abbreviated injury scale; 1: minor injury, 2: moderate injury, 3: serious injury, 4: severe injury, 5: critical injury, 6: maximum/fatal injury; $p < 0.000$; Pearson Chi-Square = 17; Cramer's V = 0.02*

Geography of AIS 2+ head injuries

Table 6 shows that moderate or worse head injuries sustained in a motor vehicle crash occur at a greater rate in a rural built environment relative to all crash incidents there. Though just 23.7% of linked crashes occurred in a rural built environment, some 30.3% of AIS 2+ head injuries took place there. Conversely, though 76.3% of linked crashes happened in a non-rural built environment, 69.7% of moderate or worse head injuries occurred there.

If we measure moderate or worse head injuries sustained in a motor vehicle crash at the zip code level across Illinois, and weight the counts per 100 thousand people in accordance with their zip code population, geographical patterns in outcomes begin to emerge. When analyzed in this manner, the zip code with the greatest count (151) of AIS 2+ head injuries and one of the greatest rates per 100k people (237) is the 60628 zip code on the south side of Chicago (see Appendix). Bordered on the east by Interstate 94, on the west by South Halsted Street, and south of East 95th Street stretching down to the Little Calumet River, this zip code has a poverty rate of 23% and a carless household rate of 24%. In Illinois, the greatest count of moderate or worse head injuries sustained in a motor vehicle crash occur in Chicago's southern 606XX zip code neighborhoods, and all six essentially share borders. Zip codes seven and eight, with both high counts and very high per 100k incidence rates, are the north-central and south-central areas of Springfield, respectively.

Figure 2 shows the poverty and carless household rates of the 100 Illinois zip codes with the greatest count of AIS 2+ head injuries across our study period (2016 through 2022). Using the 2019 American Community Survey 5-Year Estimates, we calculate an average Illinois poverty rate of 11.7% and an average carless household rate of 5.78% (Census, 2019). **Figure 2** shows that about 75% of these high-incident zip codes have an above average poverty rate, with many easily doubling the average. Also evident is the extremely high rate of carless households, with many of the high-incident zip codes at four or five times the state average.

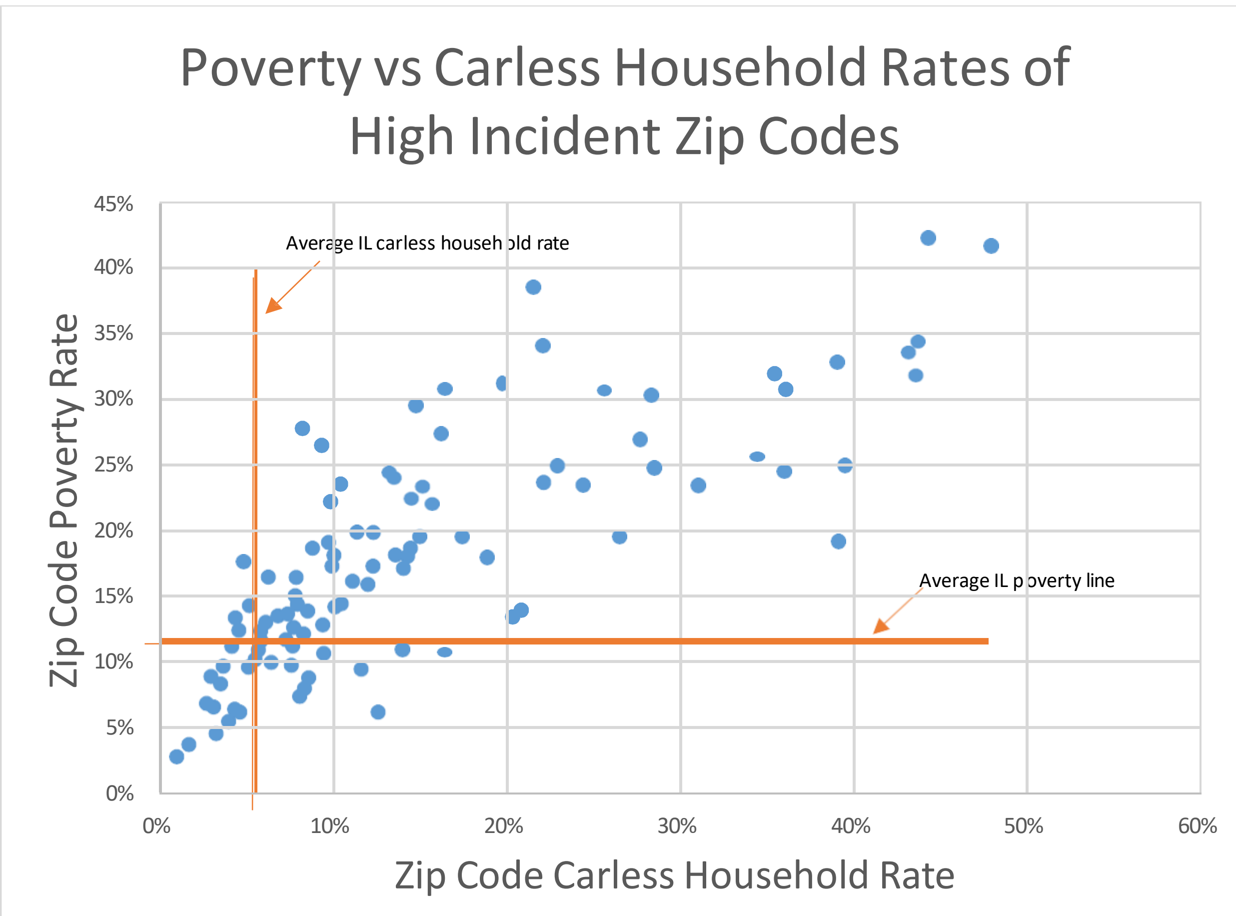
Table 6: AIS 2+ head injuries by built environment

			Head 2+		
			0	1	Total
Rural	0	Count	305890	7950	313840
		% within Rural	97.5%	2.5%	100.0%
		% within Head 2+	76.5%	69.7%	76.3%
		% of Total	74.4%	1.9%	76.3%
	1	Count	93930	3462	97392

	% within Rural	96.4%	3.6%	100.0%
	% within Head 2+	23.5%	30.3%	23.7%
	% of Total	22.8%	0.8%	23.7%
Total	Count	399820	11412	411232
	% within Rural	97.2%	2.8%	100.0%
	% within Head 2+	100.0%	100.0%	100.0%
	% of Total	97.2%	2.8%	100.0%

p < 0.000; Pearson Chi-Square = 287; Cramer's V = 0.026

*Figure 2: Poverty and carless household rates of 100 zip codes with the most AIS2+ head injuries sustained in a motor vehicle crash in Illinois, 2016-2022**



**See Appendix for complete data set*

The propensity for rural areas to contain additional pickup trucks relative to non-rural areas is not necessarily new knowledge. However, **Table 7** works to associate some numbers with the phenomenon in the context of crashes, head, and other injuries. Occupants of crashed pickup trucks are twice as likely to be in a rural setting compared to a non-rural setting. Though occupants of linked crashes in a rural built environment represent 23.7% of cases, 39.6% of crashed pickup trucks occur in a rural setting. The prevalence of the other three vehicle types by geographical location are each about at parity with their prevalence in the data.

Table 7: Crashed vehicle type by built environment

			Vehicle Type				Total
			Passenger	Pickup	SUV	Van/Minivan	
Rural	0	Count	219548	15409	60534	18349	313840
		% within Rural	70.0%	4.9%	19.3%	5.8%	100.0%
		% within Vehicle Type	77.5%	60.4%	77.4%	75.5%	76.3%
		% of Total	53.4%	3.7%	14.7%	4.5%	76.3%
	1	Count	63630	10092	17716	5954	97392
		% within Rural	65.3%	10.4%	18.2%	6.1%	100.0%
		% within Vehicle Type	22.5%	39.6%	22.6%	24.5%	23.7%
		% of Total	15.5%	2.5%	4.3%	1.4%	23.7%
Total		Count	283178	25501	78250	24303	411232
		% within Rural	68.9%	6.2%	19.0%	5.9%	100.0%
		% within Vehicle Type	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	68.9%	6.2%	19.0%	5.9%	100.0%

Discussion

The analysis presented here demonstrates that moderate or severe head injuries are more likely to occur among occupants of crashed pickup trucks. The analysis also shows that crashes involving pickup trucks are more likely to occur in rural areas. Yet, the people in Illinois at the greatest risk of head injury resulting from a crash reside largely in the very poor urban neighborhoods of southern Chicago and central Springfield. In addition to very elevated rates of impoverishment, and in a cruel irony, these same at-risk neighborhoods have unreliable and limited access to motor vehicles. Additional investigation is necessary to better understand what is causing the people of these disadvantaged and disproportionately affected neighborhoods to sustain head injuries at such a high rate.

Males, especially White males, are highly overrepresented in moderate or severe head injury outcomes sustained as occupants of pickup trucks. Similarly, all non-Hispanic road users are overrepresented. Those of Hispanic ethnicity are slightly overrepresented as occupants of crashed SUVs relative to their share of all crashed vehicle types, yet they are underrepresented as occupants of crashed pickup trucks. We found some evidence in these data supporting the idea that some Hispanics do not identify with any of the race options and opt to select the "Other" category instead.

Despite common beliefs, this investigation was unable to show that teenagers were safer in large vehicles. In fact, the evidence presented here may point in the opposite direction. Teenaged drivers of pickup trucks suffered moderate or severe head injuries at higher rates than teenaged drivers of other vehicle types. Teenaged drivers of all vehicle types were more likely than non-teenaged drivers to suffer an AIS 2+ head injury resulting from a crash. Without controlling for other potentially contributing crash factors, it cannot be asserted that the pickup truck alone were responsible for the worst injury outcomes. Still, additional training and certification requirements for teenage drivers to operate pickup trucks may help prevent them from sustaining severe head injuries.

This study does not distinguish between unibody SUVs and the rigid truck-based body-on-frame type of SUV. Given similar manufacturing platforms, occupants of truck-based SUVs likely have similar crash outcomes to those in standard pickup trucks – that is, worse outcomes relative to other vehicle types. Occupants of vehicles struck by truck-based SUVs also likely face similar outcomes to those struck by standard pickup trucks – that is, worse outcomes relative to being struck by other vehicle types. This study also does not distinguish between various crash scenarios or size and heft mismatches in colliding vehicle types. Future studies should control for variations in SUV frame manufacturing to better understand differences in crash outcomes across the growing and increasingly diverse SUV fleet. Successive studies should also delve deeper into why occupants of pickup trucks suffer more injurious outcomes relative to occupants of other vehicle types. These worse outcomes may be a result of the physics of pickup trucks or may be attributable to the characteristics of the typical driver of that vehicle type.

References

Atwood, Jon, Eun Young Noh, and Matthew J. Craig. 2023. “Female crash fatality risk relative to males for similar physical impacts.” *Traffic Injury Prevention*, *24*(sup1), S1–S8. https://doi.org/10.1080/15389588.2023.2177845.

Brett, Benjamin L., Raquel C. Gardner, Jonathan Godbout, Kristen Dams-O’Connor, and C. Dirk Keene. 2022. "Traumatic brain injury and risk of neurodegenerative disorder." *Biological psychiatry* 91, no. 5: 498-507.

Brumbelow, Matthew L., and Jessica S. Jermakian. 2021. “Injury risks and crashworthiness benefits for females and males: Which differences are physiological?” *Traffic Injury Prevention*, *23*(1), 11–16. https://doi.org/10.1080/15389588.2021.2004312.

Carroll, Christopher P., Joseph A. Cochran, Janet P. Price, Clare E. Guse, Marjorie C. Wang. 2010. “The AIS-2005 Revision in Severe Traumatic Brain Injury: Mission Accomplished or Problems for Future Research?” *Ann Adv Automot Med*. 2010;54:233-8. PMID: 21050606; PMCID: PMC3242550.

Classen, Sherrilene, Justin Mason, Seung Woo Hwangbo, James Wersal, Jason Rogers, and Virginia Sisiopiku “Older drivers’ experience with automated vehicle technology.” 2021 *Journal of Transport & Health*, Volume 22, 2021, 101107, ISSN 2214-1405, https://doi.org/10.1016/j.jth.2021.101107.

Cox, Aimee and Jessica B. Cicchino, 2021. “Continued trends in older driver crash involvement rates in the United States: Data through 2017–2018.” *Journal of Safety Research*, Volume 77, Pages 288-295, ISSN 0022-4375, https://doi.org/10.1016/j.jsr.2021.03.013.

Edwards, Mickey, and Daniel Leonard. 2022. “Effects of large vehicles on pedestrian and pedal-cyclist injury severity.” *Journal of Safety Research,* Volume 82, Pages 275-282, ISSN 0022-4375, https://doi.org/10.1016/j.jsr.2022.06.005.

Forman, Jason, Gerald S. Poplin, C. Greg Shaw, Timothy L. McMurry, Kristin Schmidt, Joseph Ash, and Cecilia Sunnevang. 2019. “Automobile injury trends in the contemporary fleet: Belted occupants in frontal collisions.” *Traffic Injury Prevention*, *20*(6), 607–612. https://doi.org/10.1080/15389588.2019.1630825.

Graham, Neil SN, Karl A. Zimmerman, Federico Moro, Amanda Heslegrave, Samia Abed Maillard, Adriano Bernini, and John-Paul Miroz et al. 2021. "Axonal marker neurofilament light predicts long-term outcomes and progressive neurodegeneration after traumatic brain injury." *Science translational medicine* 13, no. 613.

Gupta, Akshay, Pushpa Choudhary, and Manoranjan Parida. 2024. “Examining risky driving behaviours: A comparative analysis of SUVs and other car types.” *Transport Policy*, Volume 152, Pages 9-20, ISSN 0967-070X. https://doi.org/10.1016/j.tranpol.2024.04.012.

Hamann, Cara, Morgan Price, Corinne Peek-Asa. 2020. "Characteristics of crashes and injuries among 14 and 15 year old drivers, by rurality." *Journal of Safety Research*, Volume 73, 2020, Pages 111-118, ISSN 0022-4375, https://doi.org/10.1016/j.jsr.2020.02.019.

Howlett, Jonathon R., Lindsay D. Nelson, and Murray B. Stein. 2022. "Mental health consequences of traumatic brain injury." *Biological psychiatry* 91, no. 5: 413-420.

Karaca-Mandic, Pinar and Jinhyung Lee. 2014. "Hospitalizations and Fatalities in Crashes With Light Trucks." *Traffic Injury Prevention*, *15*(2), 165–171. https://doi.org/10.1080/15389588.2013.803279.

Kim, Woon, A. M. Svancara, and T. Kelley-Baker. 2020. "Understanding the impact of road design characteristic on teen driver's fatality." *Traffic Injury Prevention*, *21*(5), 313–318. https://doi.org/10.1080/15389588.2020.1753038.

Linder, Astrid, and Mats Y. Svensson. 2019. "Road safety: the average male as a norm in vehicle occupant crash safety assessment." *Interdisciplinary Science Reviews*, *44*(2), 140–153. https://doi.org/10.1080/03080188.2019.1603870.

Lopez, Mark Hugo, Jens Manuel Krogstad, and Jeffrey S. Passel. 2023. "Who is Hispanic?" *Pew Research Center.* https://pewrsr.ch/3sAlYAy.

McGlincy, Michael H. 2021. LinkSolv. Strategic Matching. Morrisonville, NY.

Monfort, Samuel S., and Joseph M. Nolan. 2019. "Trends in aggressivity and driver risk for cars, SUVs, and pickups: Vehicle incompatibility from 1989 to 2016." *Traffic Injury Prevention*, 20(sup1), S92–S96. https://doi.org/10.1080/15389588.2019.1632442.

Rahman, M. Ashifur, Md. Mahmud Hossain, Elisabeta Mitran, and Xiaoduan Sun. 2021. "Understanding the contributing factors to young driver crashes: A comparison of crash profiles of three age groups." *Transportation Engineering*, Volume 5, 100076, ISSN 2666-691X.

Rapoport, Mark J., Justin N. Chee, Nadia Aljenabi, Patrick A. Byrne, Gary Naglie, Frances Ilari, Yoassry Elzohairy, Evelyn Vingilis, and Benoit H. Mulsant. 2021. "Impact of COVID-19 on motor vehicle injuries and fatalities in older adults in Ontario, Canada." *Accident Analysis & Prevention*, Volume 157, 106195, ISSN 0001-4575, https://doi.org/10.1016/j.aap.2021.106195.

Teoh, Eric R., and Joseph M. Nolan. 2012. "Is Passenger Vehicle Incompatibility Still a Problem?" *Traffic Injury Prevention*, *13*(6), 585–591. https://doi.org/10.1080/15389588.2012.676222.

Ulfarsson, Gudmundur F. and Fred L. Mannering. "Differences in male and female injury severities in sport-utility vehicle, minivan, pickup and passenger car accidents." *Accident Analysis & Prevention*. Volume 36, Issue 2, 2004. Pages 135-147, ISSN 0001-4575, https://doi.org/10.1016/S0001-4575(02)00135-5.

United States Census Bureau. 2019. *2019 American Community Survey (ACS) 5-Year Estimates.*

Wenzel, Thomas P. and Marc Ross. 2005. “The effects of vehicle model and driver behavior on risk.” *Accident Analysis & Prevention*. Volume 37, Issue 3. Pages 479-494. ISSN 0001-4575. https://doi.org/10.1016/j.aap.2004.08.002.

Appendix

Table of 100 Illinois zip codes with the most head injuries of AIS 2+ (moderate or worse) sustained as an occupant of a motor vehicle involved in a crash.

Zip code; AIS 2+ head injury per 100k at zip code; count of AIS 2+ head injury at zip code; carless household rate of zip code, poverty rate of zip code

ZipCode	Rate100k	Count	CarlessRate	PovRate
60628	237.1939	151	24%	23%
60623	158.2376	128	28%	30%
60619	203.0124	124	34%	25%
60617	145.3174	121	22%	24%
60629	109.3464	120	19%	18%
60620	156.6346	105	28%	25%
62702	300.4005	99	13%	25%
62703	351.2545	98	15%	29%
60639	107.4384	94	17%	19%
60643	189.7142	92	10%	14%
60085	133.3005	92	12%	20%
60644	199.3254	91	43%	34%
60651	136.4884	86	23%	25%
60636	280.974	84	36%	32%
60624	223.9674	77	44%	42%
60649	168.3023	77	43%	32%
60632	82.89645	74	15%	19%
62521	206.5523	72	8%	16%
62704	168.6006	68	8%	15%
60609	112.252	68	28%	27%
60804	83.41	68	11%	16%
60608	93.77398	66	26%	19%
60612	201.7193	65	36%	31%
60411	113.9851	65	11%	24%
60827	218.0105	62	26%	30%
60641	89.1958	62	14%	11%
60634	83.03868	62	8%	8%
60618	63.46184	60	16%	10%
60652	136.8973	59	10%	13%
60016	100.9876	59	7%	10%
60426	204.1175	58	16%	31%
62526	191.964	58	11%	20%
60637	132.3446	58	44%	35%
60901	165.2509	57	14%	23%
60647	65.34824	57	21%	14%
60453	100.9555	56	8%	10%

60505	75.3894	56	5%	17%
60073	89.76514	55	3%	9%
60621	192.8395	53	48%	42%
60435	109.7649	53	9%	14%
60638	90.63702	53	9%	9%
60402	84.82579	53	8%	12%
60653	153.2943	50	39%	33%
60506	86.27969	47	7%	13%
60440	88.72772	46	4%	8%
60409	123.1359	45	14%	18%
60630	80.20533	45	12%	9%
61604	155.8074	44	14%	17%
60099	147.9091	44	10%	17%
61104	216.4279	42	21%	38%
60406	166.3366	42	14%	18%
60120	83.47245	42	4%	13%
61102	243.4535	41	9%	27%
61554	102.9504	41	7%	14%
60586	86.45776	41	1%	3%
61108	145.9641	40	6%	13%
60446	103.0742	40	3%	7%
60462	101.3094	40	3%	5%
60123	84.54336	40	7%	12%
60419	175.2258	39	10%	22%
60625	50.49197	39	20%	13%
61109	141.68	38	6%	16%
61107	128.4478	38	8%	11%
60030	105.4179	38	5%	6%
61603	224.801	37	22%	34%
61103	163.1034	37	16%	22%
60110	95.18175	37	5%	14%
61821	117.1608	36	8%	14%
60477	95.8926	36	5%	10%
60014	75.47012	36	3%	7%
60616	69.9355	36	31%	23%
60031	90.57971	34	4%	5%
60115	82.59845	34	8%	28%
61938	155.2065	33	9%	19%
60153	141.1644	33	12%	16%
61614	119.0562	33	8%	7%
60459	115.9726	33	6%	10%
62301	106.0275	33	12%	17%
60659	77.96258	33	15%	23%
60429	212.5399	32	11%	14%

60914	117.7596	32	4%	10%
60046	92.9638	32	2%	4%
61101	162.3547	31	20%	31%
60077	112.9614	31	10%	11%
60645	66.34848	31	15%	20%
60428	246.5281	30	10%	19%
61802	159.2526	30	10%	18%
60098	94.43465	30	6%	12%
61832	89.08157	30	16%	27%
60626	63.48938	30	40%	25%
62568	206.2589	29	8%	13%
60087	110.6406	29	4%	11%
61008	86.49487	29	6%	12%
60615	72.40406	29	36%	24%
60056	53.26476	29	4%	6%
60640	42.66651	29	39%	19%
60064	188.8447	28	13%	24%
60443	131.9386	28	6%	11%
61111	121.6281	28	5%	12%
60631	96.61836	28	13%	6%

Disclaimer

Funding for this research was made possible (in part) by the Illinois Department of Public Health (IDPH) through funds from the Illinois Department of Transportation (IDOT), 22-0343-03. The views expressed in written conference materials or publications and by speakers and moderators do not necessarily reflect the official policies of IDPH or IDOT, nor does the mention of trade names, commercial practices, or organizations imply endorsement by the U.S. Government.