# The association between pedestrian crash types and passenger vehicle types

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## Contents

## ABSTRACT

**Introduction**: This is the first known study that examines the association between common pedestrian crash types and passenger vehicle types.

**Method**: The analysis included single-vehicle, single-pedestrian crashes from two data sets: North Carolina state crash data and the Fatality Analysis Reporting System (FARS). We performed separate multinomial logistic regression analyses of major pedestrian crash types occurring at or near intersections and at nonintersections.

**Results**: At or near intersections, minivans, large vans, pickups, and SUVs (collectively known as light truck vehicles, or LTVs) were more likely than cars to be involved in crossing-roadway–vehicle-turning-left crashes versus crossing-roadway–vehicle-not-turning crashes. LTVs were also more likely involved in fatal crossing-roadway–vehicle-turning-right crashes at or near intersections versus crossing-roadway–vehicle-not-turning crashes when compared with cars. At nonintersections, LTVs were associated with increased odds of walking-along-roadway crashes relative to crossing-roadway–vehicle-not-turning crashes when compared with cars.

**Conclusions**: LTVs were more likely to be involved in certain pedestrian crash types, implying a potentially problematic visibility of pedestrians near the front corners of these vehicles.

**Practical applications**: More research is needed to examine A-pillar blind zones by vehicle type. If it is found that LTVs have larger blind zones, automakers should consider ways to design the A-pillars of these vehicles to minimize blind zones while maintaining pillar strength. Doing this could improve pedestrian safety around these increasingly popular larger vehicles.

**Keywords:** pedestrian crash types, light truck vehicles, A-pillar blind zones

# 1 INTRODUCTION

Pedestrians are one of the most vulnerable road user groups. The number of pedestrians killed in motor vehicle crashes in the United States has been increasing nearly every year since reaching its lowest point in 2009. Pedestrian crash deaths increased 51% from 2009 to 2019. In 2019, a total of 6,205 pedestrians were killed, accounting for 17% of all crash fatalities, and approximately 75,000 pedestrians were injured in motor vehicle crashes (Insurance Institute for Highway Safety [IIHS], 2021).

Information on pedestrian crashes such as crash types can support the development of effective countermeasures to reduce the occurrence and severity of these crashes. Pedestrian crash typing methods were first developed in the 1970s to classify crashes based on identified sequences of events leading to them (Snyder & Knoblauch, 1971). The most up-to-date crash typing methods are incorporated in the Pedestrian and Bicycle Crash Analysis Tool (PBCAT) (Harkey et al., 2006). Tools such as the Pedestrian Safety Guide and Countermeasure Selection System (Zegeer et al., 2013) help practitioners match engineering and enforcement countermeasures to the crash types they effectively target.

Pedestrian crash typing of those occurring in North Carolina during 2012–2016 found that the three most common crash types were where

- a pedestrian was crossing the roadway and a vehicle was moving straight (crossing roadway–vehicle not turning),
- a pedestrian was standing or walking along the roadway on the edge of a travel lane or on a shoulder or sidewalk and was struck by a vehicle approaching from the rear or the front (walking along roadway), and
- a pedestrian was crossing the roadway and a vehicle was turning (crossing roadway–vehicle turning) (Thomas et al., 2018).

These three crash types most frequently occurred at nonintersections in urban areas, at nonintersections in rural areas, and at intersections in urban areas, respectively.

While engineering and enforcement countermeasures can be identified based on pedestrian crash types, vehicle type also plays a role in these crashes. Previous research investigating the effect of vehicle type on pedestrian injury severity found that SUVs, pickups, and passenger vans (minivans and large vans), collectively known as light truck vehicles (LTVs), were associated with increased injury risks to pedestrians when compared with cars, due to their high and blunt front ends (Ballesteros et al., 2004; Lefler & Gabler, 2004; Longhitano et al., 2005; Monfort & Mueller, 2020; Roudsari et al., 2004; Roudsari et al., 2005). The association between vehicle types and pedestrian crash types is not yet clear.

This study examined the association between common pedestrian crash types and passenger vehicle types by using two data sets: North Carolina state police-reported crash data with all injury severity levels and the Fatality Analysis Reporting System (FARS), a national census of fatal crashes. The analysis accounted for driver- and pedestrian-related factors such as age and gender, rural or urban settings, and environment factors such as light and weather conditions. The aim was to provide new insights into the vehicle characteristics associated with pedestrian crash risk, which in turn could help automakers improve vehicle designs to enhance the safety of nonmotorized road users.

# 2 METHOD

## 2.1 Data

Crashes involving a single passenger vehicle and a single pedestrian on roadways were included in the analysis. Definitions of pedestrian crash types can be found in the PBCAT manual (Harkey et al., 2006).

### *2.1.1 North Carolina pedestrian crash data*

Data on police-reported pedestrian crashes in North Carolina during 2010–2018 were obtained from the Highway Safety Research Center at the University of North Carolina. The data contain pedestrian crash types and crash locations in relation to intersections coded by following the PBCAT typology. Vehicle Identification Numbers (VINs) of the vehicles involved were obtained when available. The VINs were decoded to obtain vehicle type using VINDICATOR, a VIN-decoding program maintained by the Highway Loss Data Institute. Vehicle information was available for passenger vehicles only and was available for 79% of vehicles involved in single-vehicle, single-pedestrian crashes.

### *2.1.2 Fatal pedestrian crash data in the U.S.*

Starting in 2014, FARS included pedestrian crash types and crash locations coded using the PBCAT crash typing method. National data for crashes involving a fatally injured pedestrian during 2014–2018 were extracted from FARS. Similar to the North Carolina data, the VINs of vehicles recorded in FARS were decoded to obtain vehicle type. Passenger vehicle type was available for 84% of vehicles involved in single-vehicle, single-pedestrian crashes.

## 2.2 Analyses

North Carolina and FARS crash data were examined separately. The analysis included the three most common crash types by location in relation to intersections: at intersections or intersection related, and at nonintersection locations. Multinomial logistic regression analysis of crash types was performed separately for each crash location, with crash-type indicators as the dependent variables.

The independent variables included passenger vehicle types (cars, minivans and large vans, pickups, and SUVs), driver age groups (16–19 years, 20–29 years, 30–69 years, and 70 years and older), pedestrian age groups (0–12 years, 13–19 years, 20–69 years, and 70 years and older), pedestrian gender, light condition (dark-lighted, dark-not lighted, dawn/dusk, and daylight), rural/urban, and weather condition (rain/sleet/snow versus clear/cloudy). In the models of intersection or intersection-related crashes for both the North Carolina and FARS data, an additional traffic-control-device indicator (traffic signal, stop sign, and no control) was included. In the model of crash types at nonintersections using FARS data, a road-type indicator (interstates and freeways, arterials, and collectors/local roads) was also included. Road type was included to account for the potential effects of impact speeds, which were not available in FARS, and driver expectations of pedestrians. Road type was not included in the model of intersection or intersection-related crashes, due to a lack of information on which of the intersecting roads was coded at the crash level. Models using North Carolina police-reported crash data did not include road type, since the data did not contain reliable road type information.

The estimated parameters for the vehicle-type indicator were used to calculate changes in the odds of examined crash types associated with passenger vehicle types, after controlling for other factors. Variables with $p$ values less than 0.05 were considered statistically significant.

# 3 RESULTS

## 3.1 North Carolina police-reported pedestrian crashes

During 2010–2018 in North Carolina, 5,505 single-passenger-vehicle, single-pedestrian crashes with known crash types occurred at intersections or were intersection related, and 7,628 occurred at nonintersection locations. Among vehicles involved in these crashes, 55.9% were cars, 22.7% were SUVs, 14.3% were pickups, and 7.2% were minivans and large vans (i.e., 44.1% were LTVs).

### *3.1.1 At intersections or intersection-related locations*

At intersections or intersection-related locations, the three most common pedestrian crash types were crossing roadway–vehicle turning (37.6%); crossing roadway–vehicle not turning (26.0%); and dash/dart-out (11.1%), where pedestrians dashed or darted out into the roadway (Table 1). Among vehicles involved in the 2,071 crossing-roadway–vehicle-turning crashes, 62.4% were turning left and 35.5% were turning right. Turning directions were unknown for the rest of the vehicles.

**Table 1**

Police-reported crashes involving a single passenger vehicle and a single pedestrian at intersections or intersection-related locations in North Carolina during 2010–2018, by crash type

| Pedestrian crash type | Frequency | % |
|---|---|---|
| Crossing roadway–vehicle turning | 2,071 | 37.6 |
| Crossing roadway–vehicle not turning | 1,431 | 26.0 |
| Dash/dart-out | 611 | 11.1 |
| Unusual circumstances | 402 | 7.3 |
| Walking along roadway | 247 | 4.5 |
| Multiple threat/trapped | 116 | 2.1 |
| Working or playing in roadway | 116 | 2.1 |
| Backing vehicle | 70 | 1.3 |
| Bus-related | 67 | 1.2 |
| Crossing driveway or alley | 37 | 0.7 |
| Unique midblock | 15 | 0.3 |
| Waiting to cross | 9 | 0.2 |
| Pedestrian in roadway–circumstances unknown | 219 | 4.0 |
| Other/unknown–insufficient details | 94 | 1.7 |
| Total | 5,505 | 100 |

We estimated a multinomial logistic regression model of the top three pedestrian crash types, with the crossing-roadway–vehicle-not-turning crash type as the reference. The crossing-roadway–vehicle-turning crashes were further categorized by vehicle turning direction. Crashes with an unknown vehicle-turning direction were not included. Full modeling results are included in Table A1 in the Appendix.

Based on the estimates for the passenger-vehicle-type indicator, when compared with cars, pickups were associated with a significant 41.9% increase in the odds of crossing-roadway–vehicle-turning-left crashes, relative to the crossing-roadway–vehicle-not-turning crashes (Table 2). Minivans, large vans, and SUVs were also more likely than cars to be involved in crossing-roadway–vehicle-turning-left crashes relative to the reference crash type.

Minivans, large vans, pickups, and SUVs, when compared with cars, did not have significantly different odds of crossing-roadway–vehicle-turning-right crashes or dash/dart-out crashes, relative to the reference crash type.

**Table 2**

Estimated changes in the odds of top police-reported pedestrian crash types in North Carolina associated with passenger vehicle types, at intersections or intersection-related locations

| Passenger vehicle type | Estimate | Estimated change in odds (%) | *p* value |
|---|---|---|---|
| *Crossing roadway–vehicle turning left vs. crossing roadway–vehicle not turning* | | | |
| Minivans and large vans vs. cars | 0.3178 | 37.4 | 0.0785 |
| Pickups vs. cars | 0.3497 | 41.9 | 0.0075 |
| SUVs vs. cars | 0.2040 | 22.6 | 0.0570 |
| *Crossing roadway–vehicle turning right vs. crossing roadway–vehicle not turning* | | | |
| Minivans and large vans vs. cars | −0.0500 | −4.9 | 0.8237 |
| Pickups vs. cars | −0.0458 | −4.5 | 0.7759 |
| SUVs vs. cars | 0.0378 | 3.9 | 0.7657 |
| *Dash/dart-out vs. crossing roadway–vehicle not turning* | | | |
| Minivans and large vans vs. cars | 0.2379 | 26.9 | 0.2977 |
| Pickups vs. cars | −0.0576 | −5.6 | 0.7503 |
| SUVs vs. cars | 0.0183 | 1.8 | 0.8967 |

*Note: P* values less than 0.05 are statistically significant.

### *3.1.2 At nonintersection locations*

At nonintersection locations, the three most common pedestrian crash types were crossing roadway–vehicle not turning (23.3%), walking along roadway (21.6%), and dash/dart-out (14.4%) (Table 3). We estimated a multinomial logistic regression model of the three crash types, with crossing roadway–vehicle not turning as the baseline (Table A2). After controlling for other factors, the estimated changes in the odds of these crash types associated with passenger vehicle types are shown in Table 4.

Minivans and large vans, pickups, and SUVs, when compared with cars, were associated with 44.5%, 79.9% and 60.5% increases, respectively, in the odds of walking-along-roadway crashes, relative to the baseline type. Passenger vehicle types were not significantly associated with the odds of dash/dart-out crashes.

**Table 3**

Police-reported crashes involving a single passenger vehicle and a single pedestrian at nonintersection locations in North Carolina during 2010–2018, by crash type

| Pedestrian crash type | Frequency | % |
|---|---|---|
| Crossing roadway–vehicle not turning | 1,779 | 23.3 |
| Walking along roadway | 1,646 | 21.6 |
| Dash/dart-out | 1,101 | 14.4 |
| Unusual circumstances | 870 | 11.4 |
| Pedestrian in roadway–circumstances unknown | 812 | 10.6 |
| Crossing driveway or alley | 345 | 4.5 |
| Backing vehicle | 234 | 3.1 |
| Working or playing in roadway | 207 | 2.7 |
| Crossing roadway–vehicle turning | 194 | 2.5 |
| Crossing expressway | 117 | 1.5 |
| Multiple threat/trapped | 84 | 1.1 |
| Unique midblock | 84 | 1.1 |
| Bus-related | 78 | 1.0 |
| Other/unknown–insufficient details | 73 | 1.0 |
| Waiting to cross | 4 | 0.1 |
| Total | 7,628 | 100 |

**Table 4**

Estimated changes in the odds of top police-reported pedestrian crash types in North Carolina associated with passenger vehicle types, at nonintersection locations

| Passenger vehicle type | Estimate | Estimated change in odds (%) | *p* value |
|---|---|---|---|
| *Walking along roadway vs. crossing roadway–vehicle not turning* | | | |
| Minivans and large vans vs. cars | 0.3684 | 44.5 | 0.0124 |
| Pickups vs. cars | 0.5874 | 79.9 | <.0001 |
| SUVs vs. cars | 0.4729 | 60.5 | <.0001 |
| *Dash/dart-out vs. crossing roadway–vehicle not turning* | | | |
| Minivans and large vans vs. cars | 0.1012 | 10.6 | 0.5414 |
| Pickups vs. cars | 0.0997 | 10.5 | 0.4690 |
| SUVs vs. cars | 0.1248 | 13.3 | 0.2471 |

*Note: P* values less than 0.05 are statistically significant.

## 3.2 Fatal pedestrian crashes in the U.S.

In FARS during 2014–2018, 5,797 fatal single-passenger-vehicle, single-pedestrian crashes with coded crash types occurred at intersections or intersection-related locations, and 14,148 occurred at nonintersection locations. Almost half (47.3%) of passenger vehicles involved were cars, 26.2% were SUVs, 19.8% were pickups, and 6.7% were minivans and large vans (i.e., 52.7% were LTVs).

### *3.2.1 At intersections or intersection-related locations*

The three most common fatal crash types at intersections or intersection-related locations nationally were the same as in North Carolina, with crossing-roadway–vehicle-not-turning crashes accounting for over half (Table 5). Of the 905 crossing-roadway–vehicle-turning crashes, vehicles were turning left in 75.5%, turning right in 20.3%, and turning directions were unknown in 4.2%.

**Table 5**

Fatal police-reported crashes involving a single passenger vehicle and a single pedestrian at intersections or intersection-related locations during 2014–2018 in the U.S., by crash type

| Pedestrian crash type | | Frequency | % |
|---|---|---|---|
| Crossing roadway–vehicle not turning | | 3,127 | 53.9 |
| Crossing roadway–vehicle turning | | 905 | 15.6 |
| Dash/dart-out | | 624 | 10.8 |
| Walking/running along roadway | | 156 | 2.7 |
| Unusual circumstances | | 88 | 1.5 |
| Multiple threat/trapped | | 46 | 0.8 |
| Backing vehicle | | 19 | 0.3 |
| Working or playing in roadway | | 19 | 0.3 |
| Bus-related | | 17 | 0.3 |
| Driveway access/driveway access related | | 12 | 0.2 |
| Waiting to cross | | 11 | 0.2 |
| Unique midblock | | 8 | 0.1 |
| Other/unknown–insufficient details | | 593 | 10.2 |
| Pedestrian in roadway–circumstances unknown | | 172 | 3.0 |
| | Total | 5,797 | 100 |

We estimated a multinomial logistic regression model of the top three fatal pedestrian crash types, with crossing roadway–vehicle not turning as the reference crash type (Table A3). Similar to the North Carolina police-reported crash analysis, the crossing-roadway–vehicle-turning crashes were further divided by vehicle turning direction.

Based on the estimates for the vehicle-type indicator, when compared with cars, minivans and large vans, pickups, and SUVs were associated with 172.0%, 269.6%, and 93.6% increases, respectively, in the odds of crossing-roadway–vehicle-turning-left crashes, relative to the reference crash type (Table 6). These increases were significant. Pickups and SUVs, when compared with cars, were associated with significantly increased odds of crossing-roadway–vehicle-turning-right crashes of 88.6% and 63.4%, respectively, relative to the reference crash type. Passenger vehicle type did not significantly affect the odds of dash/dart-out crashes.

**Table 6**

Estimated changes in the odds of top fatal pedestrian crash types in the U.S. associated with passenger vehicle types, at intersections or intersection-related locations

| Parameter | Estimate | Change in odds (%) | *p* value |
|---|---|---|---|
| *Crossing roadway–vehicle turning left vs. crossing roadway–vehicle not turning* | | | |
| Minivans and large vans vs. cars | 1.0007 | 172.0 | <.0001 |
| Pickups vs. cars | 1.3072 | 269.6 | <.0001 |
| SUVs vs. cars | 0.6605 | 93.6 | <.0001 |
| *Crossing roadway–vehicle turning right vs. crossing roadway–vehicle not turning* | | | |
| Minivans and large vans vs. cars | 0.3598 | 43.3 | 0.2835 |
| Pickups vs. cars | 0.6342 | 88.6 | 0.0063 |
| SUVs vs. cars | 0.4910 | 63.4 | 0.0230 |
| *Dash/dart-out vs. crossing roadway–vehicle not turning* | | | |
| Minivans and large vans vs. cars | 0.1021 | 10.7 | 0.6119 |
| Pickups vs. cars | −0.0442 | −4.3 | 0.7513 |
| SUVs vs. cars | 0.0416 | 4.2 | 0.7205 |

*Note: P* values less than 0.05 are statistically significant.

### *3.2.2 At nonintersection locations*

Nationwide, the most common fatal crash types at nonintersection locations were the same as in North Carolina (Table 7). We estimated a similar multinomial logistic regression model (Table A4). Pickups and SUVs, when compared with cars, were associated with significant 51.0% and 25.3% increases in the odds of walking/running-along-roadway crashes, relative to the reference crash type (Table 8). Passenger vehicle type was not found to significantly affect the odds of dash/dart-out crashes.

**Table 7**

Fatal police-reported crashes involving a single passenger vehicle and a single pedestrian at nonintersection locations during 2014–2018 in the U.S., by crash type

| Pedestrian crash type | Frequency | % |
|---|---|---|
| Crossing roadway–vehicle not turning | 5,332 | 37.7 |
| Walking/running along roadway | 2,502 | 17.7 |
| Dash/dart-out | 1,241 | 8.8 |
| Crossing expressway | 878 | 6.2 |
| Unusual circumstances | 792 | 5.6 |
| Backing vehicle | 182 | 1.3 |
| Unique midblock | 161 | 1.1 |
| Working or playing in roadway | 136 | 1.0 |
| Driveway access/driveway access related | 107 | 0.8 |
| Crossing roadway–vehicle turning | 76 | 0.5 |
| Bus-related | 48 | 0.3 |
| Multiple threat/trapped | 29 | 0.2 |
| Waiting to cross | 16 | 0.1 |
| Other/unknown–insufficient details | 1,390 | 9.8 |
| Pedestrian in roadway–circumstances unknown | 1,258 | 8.9 |
| Total | 14,148 | 100 |

**Table 8**

Estimated changes in the odds of top three fatal pedestrian crash types in the U.S. associated with passenger vehicle types, at nonintersection locations

| Parameter | Estimate | Change in odds (%) | *p* value |
|---|---|---|---|
| *Walking/running along roadway vs. crossing roadway–vehicle not turning* | | | |
| Minivans and large vans vs. cars | 0.1927 | 21.3 | 0.1115 |
| Pickups vs. cars | 0.4122 | 51.0 | <.0001 |
| SUVs vs. cars | 0.2253 | 25.3 | 0.0013 |
| *Dash/dart-out vs. crossing roadway–vehicle not turning* | | | |
| Minivans and large vans vs. cars | −0.1409 | −13.1 | 0.3491 |
| Pickups vs. cars | −0.0145 | −1.4 | 0.8792 |
| SUVs vs. cars | 0.0315 | 3.2 | 0.7077 |

*Note: P* values less than 0.05 are statistically significant.

# 4 DISCUSSION

This is the first known study that examines the association between passenger vehicle types and pedestrian crash types, by using a state crash data set and a national fatal-crash data set. Larger passenger vehicles such as pickups and SUVs were more likely to be involved in crashes where vehicles were turning at or near intersections, and in crashes where pedestrians were standing, walking, or running on or near the edge of a travel lane at nonintersection locations. The findings can be used to help identify the characteristics of larger passenger vehicles that are associated with increased crash risks to pedestrians.

For those crashes in which increased odds were associated with larger passenger vehicles, pedestrians were likely near the left or right front corners of the vehicles within A-pillar blind zones prior to crashes, as opposed to directly in front of the vehicles. It is possible that the size or geometry of A-pillars among larger passenger vehicles contributed to their overinvolvement in these crash types. Larger passenger vehicles need stronger pillars to support their heavier weight in the event of a rollover, and one way to improve the strength is with wider pillars (Pipkorn et al., 2011). Using stronger materials, for example, is another way.

While stronger pillars better protect vehicle occupants, larger A-pillars can increase the crash risks for road users outside the vehicles. An examination of 56 passenger vehicles found that the geometry of A-pillars affected the size and location of high-obscuration regions due to A-pillars, and pedestrians in these obscured regions would possibly be undetected by drivers during turning maneuvers (Reed, 2008). Larger A-pillars increased the sizes of blind zones. Additionally, A-pillars closer to the forward line of sight moved blind zones closer to vehicle travel paths, which could pose greater risks to pedestrians. Ogawa et al. (2013) found that pedestrian crashes were more likely to occur as the size of the A-pillar blind zone became larger. Sivak et al. (2007) found that the frequency of lane-changing crashes increased with wider A-pillars, because the A-pillars obstructed the drivers' visibility of an adjacent lane to the front. However, because there is no known research that systematically assesses A-pillar design by vehicle type, the hypothesis that larger vehicles' overinvolvement in certain pedestrian crash types may be caused by larger A-pillars still needs to be investigated.

Other than vehicle types, the analysis included factors related to pedestrians, drivers, and environment, which were also found to affect the probabilities of pedestrian crash types. For example, pedestrian crashes involving turning vehicles were more likely to occur at intersections with traffic signals or stop signs, compared with no control. This is possibly due to more vehicle turning or pedestrian-crossing activities at traffic-device-controlled intersections, which may warrant additional signs or markings to warn drivers and pedestrians of potential conflicts. For the dash/dart-out crash type, pedestrians ages 12 years or younger were associated with the highest increases in the odds, followed by pedestrians between 13 and 19 years old. This is consistent with previous research, which found that this crash type primarily involved children ages 5 to 14 years and accounted for the largest proportion of injuries to child pedestrians (Stevenson et al., 2015). These types of crashes may also be mitigated by lowering speed limits along streets where pedestrians are likely to cross midblock.

Vehicle type results could have been affected by how or where those vehicles were driven, in addition to vehicle design. We attempted to account for this by including nonvehicle factors. For example, larger passenger vehicles are more common in rural areas (Lowell et al., 2020). As a result, they are possibly overinvolved in crashes that are more likely to occur in rural areas, such as walking-along-roadway crashes. After controlling for the confounding rural/urban variable, larger vehicle type effects still persist.

Safe vehicles are an essential part of a safe system, and together with other components such as safe roads, they provide layers of protection for road users. Pedestrian automatic emergency braking (AEB) systems can avoid or mitigate a crash with a pedestrian by automatically applying brakes. These systems are effective in reducing pedestrian crashes (Cicchino, 2022; Wakeman et al., 2019). Cicchino (2022) also found that pedestrian AEB was not effective in reducing pedestrian crashes where a vehicle was turning. Greater effectiveness could be achieved if pedestrian AEB could better detect pedestrians during turning, especially when installed in larger vehicles, given that these vehicles were more likely than cars to hit a pedestrian when turning. It has been well established that vehicle design characteristics affect pedestrian injury severity. Modifications to the front structures of passenger vehicles, such as more space between the hood and engine, hood airbags, hoods that automatically pop up upon impact, and contoured front ends, have been shown to reduce pedestrian injury severity in vehicle tests (Strandroth et al., 2014). Examining how vehicle design affects pedestrian crash involvement could further improve pedestrian safety.

The study found that larger passenger vehicles were overinvolved in certain pedestrian crashes, which points to the potentially problematic visibility of pedestrians near the front corners of these vehicles. As the vehicle market continues to move away from cars to light truck vehicles, especially SUVs and pickups (Environmental Protection Agency, 2021), research has found that pedestrian fatalities involving SUVs increased more than those involving other vehicle types (Hu & Cicchino, 2018). More research should be done to examine A-pillar blind zones by vehicle type. If it is found that larger passenger vehicles have larger blind zones, automakers should consider ways to design the A-pillars of these vehicles to minimize blind zones while maintaining pillar strength. This could improve pedestrian safety around these increasingly popular larger vehicles.

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# 7. APPENDIX

**Table A1.** Multinomial logistic regression modeling results of police-reported pedestrian crash types in North Carolina at intersections or intersection-related locations

| | Crossing roadway–vehicle turning left vs. crossing roadway–vehicle not turning | | | Crossing roadway–vehicle turning right vs. crossing roadway–vehicle not turning | | | Dash/dart-out vs. crossing roadway–vehicle not turning | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | Estimate | Change in odds (%) | *p* value | Estimate | Change in odds (%) | *p* value | Estimate | Change in odds (%) | *p* value |
| Intercept | −1.2193 | n/a | <.0001 | −1.8609 | n/a | <.0001 | −0.67 | n/a | 0.0044 |
| *Passenger vehicle type* | | | | | | | | | |
| Minivans and large vans vs. cars | 0.3178 | 37.4 | 0.0785 | −0.05 | −4.9 | 0.8237 | 0.2379 | 26.9 | 0.2977 |
| Pickups vs. cars | 0.3497 | 41.9 | 0.0075 | −0.0458 | −4.5 | 0.7759 | −0.0576 | −5.6 | 0.7503 |
| SUVs vs. cars | 0.2040 | 22.6 | 0.0570 | 0.0378 | 3.9 | 0.7657 | 0.0183 | 1.8 | 0.8967 |
| *Driver age group (years)* | | | | | | | | | |
| 16–19 vs. 30–69 | −0.0871 | −8.3 | 0.6421 | −0.2057 | −18.6 | 0.3629 | −0.2953 | −25.6 | 0.2247 |
| 20–29 vs. 30–69 | −0.0147 | −1.5 | 0.8888 | −0.1573 | −14.6 | 0.2136 | 0.0239 | 2.4 | 0.8574 |
| 70+ vs. 30–69 | −0.3001 | −25.9 | 0.0565 | −0.3786 | −31.5 | 0.041 | −0.6331 | −46.9 | 0.0065 |
| *Pedestrian age group (years)* | | | | | | | | | |
| 0–12 vs. 20–69 | −0.5171 | −40.4 | 0.0450 | −0.7193 | −51.3 | 0.0330 | 1.9654 | 613.8 | <.0001 |
| 13–19 vs. 20–69 | −0.4900 | −38.7 | 0.0004 | −0.4637 | −37.1 | 0.0052 | 1.2060 | 234.0 | <.0001 |
| 70+ vs. 20–69 | −0.0304 | −3.0 | 0.8791 | 0.1587 | 17.2 | 0.4761 | −1.5636 | −79.1 | 0.0028 |
| *Pedestrian gender* | | | | | | | | | |
| Female vs. male | 0.3696 | 44.7 | <.0001 | 0.2753 | 31.7 | 0.0077 | −0.5455 | −42.0 | <.0001 |
| *Light condition* | | | | | | | | | |
| Dark-lighted vs. daylight | −0.8171 | −55.8 | <.0001 | −1.3031 | −72.8 | <.0001 | −0.4226 | −34.5 | 0.0008 |
| Dark-not lighted vs. daylight | −0.8123 | −55.6 | <.0001 | −1.5542 | −78.9 | <.0001 | −0.7422 | −52.4 | 0.0006 |
| Dawn/dusk vs. daylight | −0.7097 | −50.8 | 0.001 | −0.4146 | −33.9 | 0.0703 | −0.4764 | −37.9 | 0.0683 |
| *Rural/Urban* | | | | | | | | | |
| Urban vs. rural | 0.4790 | 61.4 | 0.0049 | 0.2597 | 29.7 | 0.2004 | 0.1675 | 18.2 | 0.4093 |
| *Weather* | | | | | | | | | |
| Rain/sleet/snow vs. clear/cloudy | 0.4517 | 57.1 | 0.0007 | −0.1264 | −11.9 | 0.4856 | −0.2198 | −19.7 | 0.265 |
| *Traffic control device* | | | | | | | | | |
| Stop and go signal vs. no control | 1.2762 | 258.3 | <.0001 | 1.9731 | 619.3 | <.0001 | −0.3444 | −29.1 | 0.0044 |
| Stop sign vs. no control | 0.7043 | 102.2 | <.0001 | 1.6393 | 415.2 | <.0001 | −0.9538 | −61.5 | <.0001 |

*Note:* n/a = not applicable.

P values less than 0.05 are statistically significant.

**Table A2.** Multinomial logistic regression modeling results of police-reported pedestrian crash types in North Carolina at nonintersection locations

| | Walking along roadway vs. crossing roadway–vehicle not turning | | | Dash/dart-out vs. crossing roadway–vehicle not turning | | |
|---|---|---|---|---|---|---|
| Parameter | Estimate | Change in odds (%) | *p* value | Estimate | Change in odds (%) | *p* value |
| Intercept | 0.2545 | n/a | 0.021 | −0.5410 | n/a | <.0001 |
| *Passenger vehicle type* | | | | | | |
| Minivans and large vans vs. cars | 0.3684 | 44.5 | 0.0124 | 0.1012 | 10.6 | 0.5414 |
| Pickups vs. cars | 0.5874 | 79.9 | <.0001 | 0.0997 | 10.5 | 0.469 |
| SUVs vs. cars | 0.4729 | 60.5 | <.0001 | 0.1248 | 13.3 | 0.2471 |
| *Driver age group (years)* | | | | | | |
| 16–19 vs. 30–69 | 0.0133 | 1.3 | 0.9327 | −0.1648 | −15.2 | 0.3427 |
| 20–29 vs. 30–69 | 0.1416 | 15.2 | 0.1395 | 0.1173 | 12.4 | 0.2536 |
| 70+ vs. 30–69 | 0.5325 | 70.3 | 0.0001 | −0.2766 | −24.2 | 0.114 |
| *Pedestrian age group (years)* | | | | | | |
| 0–12 vs. 20–69 | −1.4937 | −77.5 | <.0001 | 1.8876 | 560.4 | <.0001 |
| 13–19 vs. 20–69 | −0.1031 | −9.8 | 0.3542 | 0.7676 | 115.5 | <.0001 |
| 70+ vs. 20–69 | −1.1712 | −69.0 | <.0001 | −0.9973 | −63.1 | 0.0007 |
| *Pedestrian gender* | | | | | | |
| Female vs. male | 0.0683 | 7.1 | 0.4125 | -0.1901 | −17.3 | 0.0397 |
| *Light condition* | | | | | | |
| Dark-lighted vs. daylight | −0.5263 | −40.9 | <.0001 | −0.5989 | −45.1 | <.0001 |
| Dark-not lighted vs. daylight | 0.4700 | 60.0 | <.0001 | −0.8578 | −57.6 | <.0001 |
| Dawn/dusk vs. daylight | 0.2687 | 30.8 | 0.1488 | −0.4071 | −33.4 | 0.0435 |
| *Rural/Urban* | | | | | | |
| Urban vs. rural | −1.1965 | −69.8 | <.0001 | 0.0775 | 8.1 | 0.4543 |
| *Weather* | | | | | | |
| Rain/sleet/snow vs. clear/cloudy | −0.1051 | −10.0 | 0.444 | −0.2895 | −25.1 | 0.0718 |

*Note:* n/a = not applicable.
*P* values less than 0.05 are statistically significant.

**Table A3.** Multinomial logistic regression modeling results of fatal pedestrian crash types in the U.S. at intersections or intersection-related locations

| | Crossing roadway–vehicle turning left vs. crossing roadway–vehicle not turning | | | Crossing roadway–vehicle turning right vs. crossing roadway–vehicle not turning | | | Dash/dart-out vs. crossing roadway–vehicle not turning | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | Estimate | Change in odds (%) | *p* value | Estimate | Change in odds (%) | *p* value | Estimate | Change in odds (%) | *p* value |
| Intercept | −2.6278 | n/a | <.0001 | −3.7436 | n/a | <.0001 | −1.3027 | n/a | <.0001 |
| *Passenger vehicle type* | | | | | | | | | |
| Minivans and large vans vs. cars | 1.0007 | 172.0 | <.0001 | 0.3598 | 43.3 | 0.2835 | 0.1021 | 10.7 | 0.6119 |
| Pickups vs. cars | 1.3072 | 269.6 | <.0001 | 0.6342 | 88.6 | 0.0063 | −0.0442 | −4.3 | 0.7513 |
| SUVs vs. cars | 0.6605 | 93.6 | <.0001 | 0.4910 | 63.4 | 0.0230 | 0.0416 | 4.2 | 0.7205 |
| *Speeding related* | | | | | | | | | |
| Yes vs. no | −0.9090 | −59.7 | 0.0028 | −0.6581 | −48.2 | 0.1742 | −0.5694 | −43.4 | 0.0097 |
| *Driver age group (years)* | | | | | | | | | |
| 16–19 vs. 30–69 | −0.3198 | −27.4 | 0.3273 | −0.5977 | −45.0 | 0.2682 | 0.1945 | 21.5 | 0.3508 |
| 20–29 vs. 30–69 | 0.1319 | 14.1 | 0.346 | −0.8406 | −56.9 | 0.0029 | 0.1048 | 11.0 | 0.3642 |
| 70+ vs. 30–69 | 0.0272 | 2.8 | 0.8794 | 0.0838 | 8.7 | 0.7426 | −0.0314 | −3.1 | 0.8594 |
| *Pedestrian age group (years)* | | | | | | | | | |
| 0–12 vs. 20–69 | 0.5671 | 76.3 | 0.0992 | 0.8217 | 127.4 | 0.0967 | 1.8286 | 522.5 | <.0001 |
| 13–19 vs. 20–69 | −1.9939 | −86.4 | 0.0002 | −0.4138 | −33.9 | 0.4022 | 0.7976 | 122.0 | <.0001 |
| 70+ vs. 20–69 | 0.5576 | 74.6 | <.0001 | 0.5593 | 74.9 | 0.0029 | −0.5691 | −43.4 | <.0001 |
| *Pedestrian gender* | | | | | | | | | |
| Female vs. male | 0.4212 | 52.4 | 0.0002 | 0.5314 | 70.1 | 0.0025 | −0.1621 | −15.0 | 0.1187 |
| *Light condition* | | | | | | | | | |
| Dark-lighted vs. daylight | −2.2679 | −89.6 | <.0001 | −2.1081 | −87.9 | <.0001 | −0.3197 | −27.4 | 0.0107 |
| Dark-not lighted vs. daylight | −2.5434 | −92.1 | <.0001 | −2.7541 | −93.6 | <.0001 | −0.2773 | −24.2 | 0.0790 |
| Dusk/dawn vs. daylight | −1.3098 | −73.0 | <.0001 | −1.3638 | −74.4 | 0.0010 | −0.0910 | −8.7 | 0.6983 |
| *Rural/urban* | | | | | | | | | |
| Urban vs. rural | 0.1965 | 21.7 | 0.4179 | 0.2734 | 31.4 | 0.4954 | 0.0324 | 3.3 | 0.8630 |
| *Traffic control device* | | | | | | | | | |
| Stop vs. no control | 2.6669 | 1339.5 | <.0001 | 2.7566 | 1474.6 | <.0001 | −1.0596 | −65.3 | 0.0264 |
| Signal vs. no control | 1.6482 | 419.8 | <.0001 | 1.7827 | 494.6 | <.0001 | −0.0727 | −7.0 | 0.4623 |
| *Weather* | | | | | | | | | |
| Rain/sleet/snow vs. clear/cloudy | 0.5765 | 78.0 | 0.0029 | 0.4064 | 50.1 | 0.2035 | 0.0297 | 3.0 | 0.8565 |

*Note:* n/a = not applicable.

*P* values less than 0.05 are statistically significant.

**Table A4.** Multinomial logistic regression modeling results of fatal pedestrian crash types in the U.S. at nonintersection locations

| | Walking/running along roadway vs. crossing roadway–vehicle not turning | | | | Dash/dart-out vs. crossing roadway–vehicle not turning | | |
|---|---|---|---|---|---|---|---|
| Parameter | Estimate | Change in odds (%) | *p* value | | Estimate | Change in odds (%) | *p* value |
| Intercept | 0.3026 | n/a | 0.0064 | | −0.8334 | n/a | <.0001 |
| *Passenger vehicle type* | | | | | | | |
| Minivans and large vans vs. cars | 0.1927 | 21.3 | 0.1115 | | −0.1409 | −13.1 | 0.3491 |
| Pickups vs. cars | 0.4122 | 51.0 | <.0001 | | −0.0145 | −1.4 | 0.8792 |
| SUVs vs. cars | 0.2253 | 25.3 | 0.0013 | | 0.0315 | 3.2 | 0.7077 |
| *Speeding related* | | | | | | | |
| Yes vs. no | 0.6152 | 85.0 | <.0001 | | −0.4655 | −37.2 | 0.0144 |
| *Driver age group* | | | | | | | |
| 16–19 vs. 30–69 | 0.3426 | 40.9 | 0.0018 | | 0.1055 | 11.1 | 0.4530 |
| 20–29 vs. 30–69 | 0.2702 | 31.0 | <.0001 | | −0.0389 | −3.8 | 0.6476 |
| 70+ vs. 30–69 | 0.000013 | 0.0 | 0.9999 | | 0.0890 | 9.3 | 0.5031 |
| *Pedestrian age group* | | | | | | | |
| 0–12 vs. 20–69 | −1.0517 | −65.1 | <.0001 | | 1.8288 | 522.6 | <.0001 |
| 13–19 vs. 20–69 | 0.7209 | 105.6 | <.0001 | | 0.9787 | 166.1 | <.0001 |
| 70+ vs. 20–69 | −1.0688 | −65.7 | <.0001 | | −0.3821 | −31.8 | 0.0004 |
| *Pedestrian gender* | | | | | | | |
| Female vs. male | −0.0494 | −4.8 | 0.4308 | | −0.1464 | −13.6 | 0.0575 |
| *Light condition* | | | | | | | |
| Dark, lighted vs. daylight | −0.7703 | −53.7 | <.0001 | | −0.6232 | −46.4 | <.0001 |
| Dark, not lighted vs. daylight | 0.2769 | 31.9 | 0.0012 | | −0.7753 | −53.9 | <.0001 |
| Dusk/dawn vs. daylight | 0.0061 | 0.6 | 0.9691 | | −0.6774 | −49.2 | 0.0008 |
| *Rural/urban* | | | | | | | |
| Urban vs. rural | −0.8404 | −56.8 | <.0001 | | −0.2569 | −22.7 | 0.0059 |
| *Road type* | | | | | | | |
| Arterials vs. collectors/local roads | −0.8706 | −58.1 | <.0001 | | 0.0708 | 7.3 | 0.4268 |
| Interstates/freeways vs. collectors/local roads | 0.3083 | 36.1 | 0.0047 | | 0.6470 | 91.0 | <.0001 |
| *Weatsher* | | | | | | | |
| Rain/sleet/snow vs. clear/cloudy | 0.0903 | 9.5 | 0.3537 | | 0.1475 | 15.9 | 0.2063 |

*Note:* n/a = not applicable.

*P* values less than 0.05 are statistically significant.