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Relative Safety Assessment for Positioning Children in Vehicles with Varying Levels of Advanced Safety Technologies

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Abstract: Recent studies suggest that advances in rear seat occupant protection are trailing while frontal crash prevention technologies have disproportionately improved front seat occupant safety. Therefore, the first objective of this study is to identify the safest seat for children by estimating injury severity by seat position using current crash data. The second objective of this study is to demonstrate that Level-2 and above (i.e., L2+) AVs will be significantly different from current vehicles regarding child injury severity, and therefore it is essential to find the safest seat for children in L2+ AVs. This study utilized data from the National Automotive Sampling System (NASS) to estimate crash injury severity by seat position in children. This study used the Injury Severity Score (ISS) as its measure of crash severity. The mean ISS for restrained children sitting in the front passenger seat was 0.494 (for model year > 2000 vehicles). The mean ISSs for second-row left and second-row right seats were 0.374 and 0.322, respectively. The second-row middle seat had 162, 98, and 71% lower mean ISSs than the front passenger, second-row left, and second-row right seats, respectively. Overall, in both restrained and unrestrained scenarios, the safest seat for a child was the second-row middle seat.

Keywords: children; autonomous vehicle; self-driving vehicle; injury severity; crashes; safety

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1. Introduction

In the United States, motor vehicle crashes are a leading cause of death among children [1]. In 2018, more than 630 children aged 12 years and younger were killed in road crashes, of whom 210 were not restrained by a seat belt or in a car seat [1]. In the same year, more than 97,000 children were injured in crashes. The proper use of child car seats reduces the risk of death to infants (aged < 1 year) by 71% and toddlers (aged 1–4 years) by 54% [2]. Booster seat use reduces the risk of serious injury by 45% for young children (aged 4–8) years [2].

While restraint use has been observed to influence child injury severity in a crash, other studies have explored the effects of the seat position on injury outcome. Previous studies have shown that seats in the rear are generally safer for occupants than the seats in the front of the vehicle [3–10]. For instance, Lennon et al. [10] observed that for children under four years of age traveling in the front seat, the relative risk of death was about twice that of traveling in the rear, and the risk of serious injury was about 60% greater. They also observed that the relative risk of death while traveling in the front seat was almost four times greater for children under one year. Similarly, Braver et al. [6] found that among children under 13 years of age, the fatality risk was 38% lower for properly restrained rear-seated children compared with those positioned in the front seat. Moreover, Durbin et al. [11] observed that children were 40% safer in the back seat than in the front when involved in a crash, with the likelihood of injury below 2% if restraint systems were used. According to Durbin et al. [7], there is a significant fatality risk reduction for restrained children aged 0–8 years in the rear compared with the front.

Although it has been established that, generally, a rear seat position is safest for children, only a very few studies [12,13] have examined which rear seat (e.g., left, right, or middle) is the safest. Mayrose and Priya [12] used 2000 to 2003 Fatality Analysis Reporting System (FARS) data to identify the safest seat in a car. Kallan et al. [13] used 1998 to 2003 insurance claim data and found that children in the rear middle seat had a 43% lower injury risk than those in the rear left and right seats. These two studies were conducted some 17 years ago, and the subject vehicles represented very different manufacturing standards and safety technologies compared with the current vehicle fleet. Other recent studies suggest that advances in rear seat occupant protection are trailing while frontal crash prevention technologies have disproportionately improved front seat occupant safety [14–17]. Tatem et al. [18] found that the rear seat carried a higher risk of fatality in newer model year vehicles (2007–2016). Another study that examined the factors associated with injury risk for pairs of front- and second-row occupants in frontal crashes indicated that the likelihood of severe injury for the second-row seated occupant of the pair increased as the crash severity increased [19]. Furthermore, according to Mitchell et al. [20], rear seat passengers sustained injuries of higher severity than front seat passengers traveling in the same vehicle when traveling in newer vehicles. The odds of sustaining injuries as rear seat occupants compared with front seat occupants and the odds of sustaining severe rather than minimal injuries were both higher. Considering the findings of recent studies, there is a need to reassess the safest seat for children in the current passenger car fleet. Therefore, the first objective of this study is to identify the safest seat for children by estimating injury severity by seat position using current crash data.

Even though the concept of Automated Vehicles (AVs) has existed for more than three decades, the transportation industry is moving towards making it widely accessible. A very small proportion of vehicles in the current vehicle fleet are already operating at Level-3 automation. Auto manufacturers are making progress towards mandating some of the Advanced Driver Assistance Systems (ADAS), such as Automatic Emergency Braking (AEB), as a standard feature in all vehicle trim and option packages [21]. Such steps are essential to eventually reach full automation. According to NHTSA, "Automatic emergency braking systems apply the vehicle's brakes automatically in time to avoid or mitigate an impending forward crash with another vehicle. NHTSA believes AEB systems represent the next wave of potentially significant advances in vehicle safety. Dynamic brake support and crash imminent braking are AEB systems that potentially save lives and reduce moderate and less severe rear-end crashes that are common on our roadways" [22]. With such improvements in vehicle technology, it will be essential to continue investigating the relative safety of seat positioning for children as vehicles gain increased levels of automation and crash dynamics and their propensities change. Hence, the second objective of this study is to demonstrate that Level-2 and above (i.e., L2+) AVs will be significantly different from current vehicles regarding child injury severity, and therefore it is essential to find the safest seat for children in L2+ AVs. This study relies on a mix of quantitative and qualitative assessments to demonstrate the need for continued research on the relative safety of seat positioning for children as vehicle designs and safety technologies evolve. As such, it is intended that this study contributes to an ongoing discussion among researchers and safety officials on child safety in AVs.

2. Materials and Methods

This study utilized data from the National Automotive Sampling System (NASS) Crashworthiness Data System (CDS) and General Estimates System (GES). NASS CDS and GES "are based on cases selected from a sample of police crash reports. CDS data focus on passenger vehicle crashes and are used to investigate injury mechanisms to identify potential improvements in vehicle design. GES data focus on the bigger overall crash picture and are used for problem size assessments and tracking trends" [23]. Both CDS and GES were ended in 2015, and new crash data collecting systems were designed to replace them. As crash investigators need to be trained for collecting data under the new systems, a staged approach has been adopted since 2017. The current study used 2006 to 2014 CDS data and 2015 GES data to avoid introducing complexity across the data sources.

Both the NASS data systems rely on survey data and have weights associated with each crash. Each row in the data represents a record of a single person involved in the crash. The analysis was conducted at the person level in SAS using the PROC SURVEY function to specifically handle survey weights. The following binary variables were created to facilitate the analysis in SAS:

- Children (0 if the person involved in the crash was older than 12 years, 1 otherwise);
- Restrained (0 if the person involved in the crash was not restrained, 1 otherwise);
- Latest vehicles (0 if the vehicle involved in the crash was older than model year (MY) 2000, 1 otherwise).

The analysis was conducted at the person level: (i.e., each row in the data represents one person involved in the crash). Since the purpose of this study is the identification of a safer seating position for children, injury severity only for children is considered. Hence, the results presented in the following sections relate specifically to children.

It is recommended to study sub-populations of the survey data while still considering the whole data to accurately estimate standard errors [24]. Hence, rather than filtering out crashes of interest for this study, the binary variables were created to specify SAS about the records of interest while still considering the whole data for standard error estimation.

This study used the Injury Severity Score (ISS) as its measure of crash severity. The ISS is calculated based on the Abbreviated Injury Scale (AIS), a 6-level anatomical injury severity classification where 0 indicates no injury and 6 is an untreatable injury. ISS is an internationally recognized scoring system that correlates with mortality, morbidity, and other severity measures. The ISS is calculated as the sum of the squares of the highest AIS code in each of the three most severely injured ISS body regions. These body regions are the head and neck, face, chest, abdomen, extremity (including pelvis), and external. ISS scores range from 1 to 75. If an injury is assigned an AIS of 6 (i.e., an untreatable injury), the ISS score is automatically assigned as 75 [25].

3. Results

Table 1 presents descriptive statistics of the data. Both weighted and unweighted frequencies, along with their percentages, are presented in the table. The weighted estimates are calculated using the weights that are presented in the data. Children aged between 0 and 12 years accounted for 7% of the people involved in crashes. Considering weights, more than 1.2 million child injury severities were examined in this study. Around 45% of the children involved in crashes were not restrained (restrained implies using either a child seat, the lap or shoulder belt, or both).

Table 1. Descriptive statistics of the data.

Variable	Weighted Frequency (%)	Unweighted Frequency (%)
Child		
No	82,190 (92.72)	35,156,169 (93.02)
Yes	6449 (7.28)	2,636,136 (6.98)
Restraint use for children		
No	2881 (44.67)	1,171,736 (44.45)
Yes	3568 (55.33)	1,464,400 (55.55)
Seat position of children		
Front right	698 (10.82)	296,054 (11.23)
Second-row left seat	1646 (25.52)	656,056 (24.89)
Second-row middle seat	835 (12.95)	332,107 (12.60)
Second-row right seat	1929 (29.91)	858,261 (32.56)
Third-row left seat	146 (2.26)	73,288 (2.78)
Third-row middle seat	67 (1.04)	24,389 (0.93)
Third-row right seat	151 (2.34)	61,659 (2.34)

Table 1. *Cont.*

Variable	Weighted Frequency (%)	Unweighted Frequency (%)
Greatest area of damage for vehicle with children		
Back	444 (6.88)	205,895 (7.81)
Front	2821 (43.74)	1,148,710 (43.58)
Left	825 (12.79	317,571 (12.05)
Right	674 (10.45)	258,809 (9.82)
Top	306 (4.74)	54,233 (2.06)
Under	13 (0.20)	7695 (0.29)
Maximum Abbreviated Injury Scale (MAIS) for children		
Not injured	2855 (44.27)	1,418,301 (53.80)
Minor	1389 (21.54)	379,431 (14.39)
Moderate	179 (2.78)	24,526 (0.93)
Serious	97 (1.50)	10,240 (0.39)
Severe	46 (0.71)	3873 (0.15)
Critical	31 (0.48)	3729 (0.14)
Maximum (untreatable)	16 (0.25)	905 (0.03)

A preliminary analysis based on the descriptive statistics indicates that the right seat in the second row was the most frequently occupied seating position in the car, with almost 30% of children, followed by second-row left (26%) and middle seat (13%). During the study period, a total of 364 children (~116,000 when weighted) were observed to be seated in the third row of the vehicle. Because of its low sample size, this seat position was not analyzed in this study. Furthermore, for about 44% of the children involved in crashes during the study period, the front of the vehicle remained the most significantly damaged side. Furthermore, more than half of the children in the weighted samples involved in the crashes were not injured at all, while about 14% had minor injuries. Approximately 1% of the children involved in the crashes sustained serious, severe, or critical injuries.

3.1. Safest Seat for Children in the Current Vehicle Fleet

To identify the safest seat in a vehicle, mean weighted ISS values were estimated by seat position for children in vehicles with MY > 2000, as presented in Figure 1.

The mean ISS for restrained children sitting in the front passenger seat was 0.494 (for MY > 2000 vehicles). The mean ISSs for the second-row left and second-row right seats were 0.374 and 0.322, respectively. The second-row middle seat had 162, 98, and 71% lower mean ISSs than the front passenger, second-row left, and second-row right seats, respectively. The standard errors for the restrained scenario were very low, explaining the little variability in the mean ISS.

Unrestrained children in the front passenger seat had a mean ISS of 1.259. The use of either lap or shoulder belts or both reduced the mean ISS by 154, 156, 109, and 89% for front passenger, second-row left, second-row middle, and second-row right seats, respectively, for children. The restraint use had a maximum benefit for the front passenger and second-row left seats compared with the other seats. The second-row middle seat had 219, 143, and 54% lower mean ISSs than the front passenger, second-row middle, and second-row right seats.

Overall, in both restrained and unrestrained scenarios, the safest seat for a child was the second-row middle seat. From Table 1, it is clear that the second-row right seat was the seat most frequently occupied by children. However, it also shows that the second-row right seat was roughly 71% and 54% more unsafe than the second-row middle seat when restrained and unrestrained, respectively. Moreover, unrestrained children sitting in the second-row middle seat were safer than restrained children sitting in the front seat.

While the second-row middle seat remained the safest seat in newer vehicles, the authors also explored the temporal changes in the injury severity of children caused by the changes in vehicle occupant protection systems, the results of which are presented in Table 2.

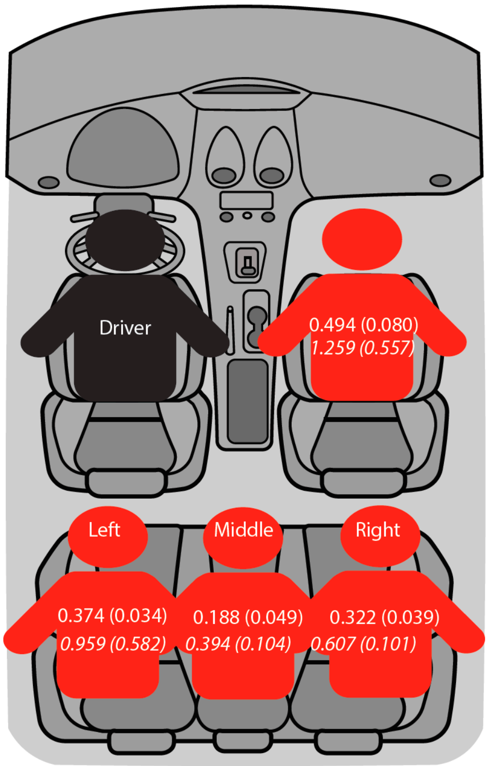

Figure 1. ISS by Seat Position for Restrained and Unrestrained Children in Vehicles with MY > 2000. Note: The values in the parenthesis are standard errors for the mean ISS. Values in italics are for unrestrained children.

Table 2. Mean ISS by Model Year and Seat Position for Restrained Children.

Seat Position	Mean ISS	Std. Error	Difference in Mean ISS	*p*-Value
Front right				
Older (2000 and before)	1.233	0.376	0.74	0.047 *
Newer (2000 and after)	0.494	0.08		
Second-row left seat				
Older	0.447	0.125	0.074	0.582
Newer	0.374	0.034		
Second-row middle seat				
Older	0.824	0.432	0.636	0.19
Newer	0.188	0.05		
Second-row right seat				
Older	0.403	0.122	0.082	0.587
Newer	0.322	0.039		

Note: * indicates significance at the 95% confidence level.

As indicated in Table 2, the mean ISS values were found to decrease in newer vehicles for all seat positions compared with older vehicles. The mean ISS for the second-row middle seat in older vehicles was higher than for the second-row left and second-row right seats in older vehicles, which contradicts the findings of Mayrose and Priya [12], and Kallan et al. [13]. The standard deviations were observed to be higher in older vehicles. This could be due to the smaller sample sizes of the older vehicles as newer vehicles are added to the samples every sampling period (CDS is designed in such a way to sample crashes involving newer model year vehicles, which could impact the sample size of older vehicles in the CDS crash data). The difference between the mean ISS of older and newer vehicles was statistically significant at a 95% confidence level for the front right seat but not for any other seat positions. The reduction in mean ISSs for the second-row left and second-row right seats was slight (0.074 and 0.082, respectively), whereas the difference for the second-row middle seat was noticeable (0.636) but not statistically significant. The results suggest that the safety of children has significantly improved for the front passenger seat over the years. Despite these improvements (which can be attributed to technologies such as AEB), it should be emphasized that the front passenger seat is still the least safe seat position for children, as indicated in Table 1.

Additionally, mean ISS values were estimated by seat position and the highest deformation side (as reported in the crash data), as presented in Figure 2. The blue bar indicates the highest deformation location for the vehicle. In situations where the most significant damage was to the front of the vehicle, and restrained children were sitting in the front passenger seat, the mean ISS was estimated to be 0.722 (Figure 2a), while the mean ISSs for the second-row left, middle and right seats were estimated as 0.340, 0.289, and 0.311, respectively. Thus, in vehicles with frontal damage, the second-row middle seat remains the safest. The mean ISS values are as expected: children sitting closest to the impact location have higher mean ISSs.

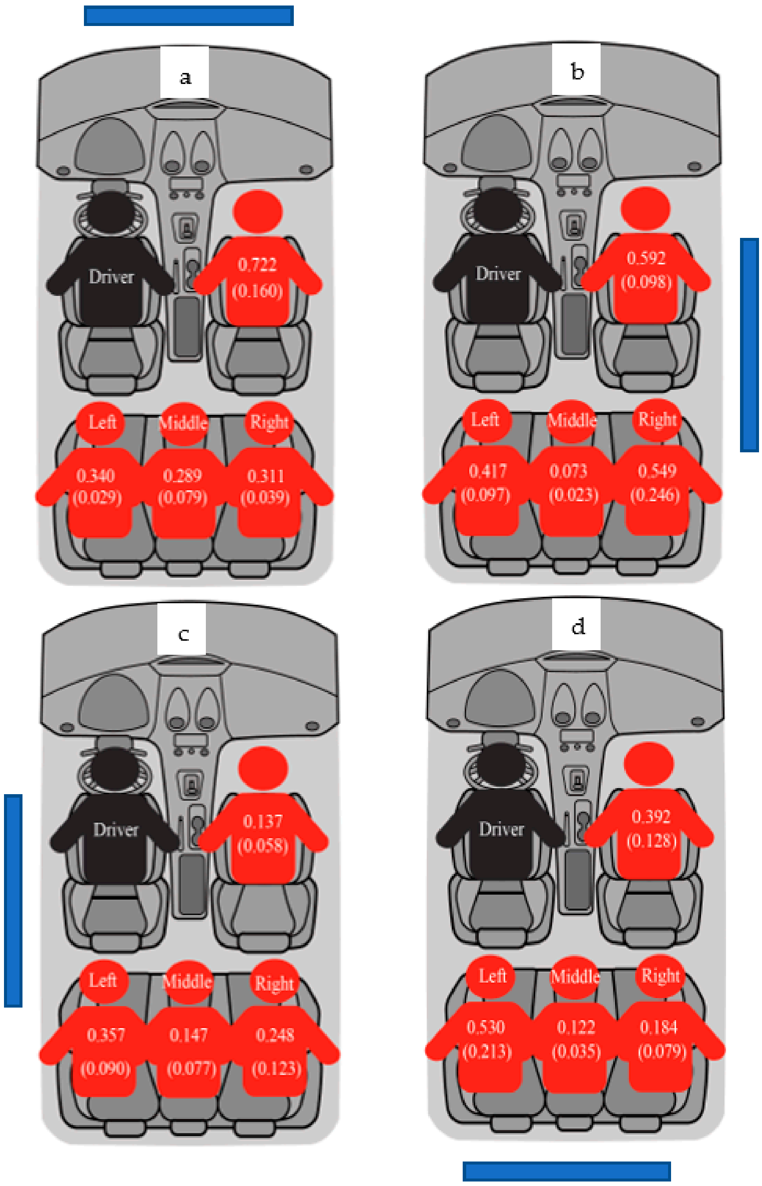

Figure 2. Restrained Children's Mean ISS by Seat Position and Greatest Area of Damage (**a**-front; **b**-right; **c**-left, **d**-rear) in Newer Vehicles.

However, the highest deformation of the vehicle is on the right; both the front passenger seat and second-row right seat have higher mean ISS values as they are closest to the impact. Restrained children sitting in the second-row seats have higher mean ISSs when the highest deformation is on the right rather than at the front. The front passenger seat has the lowest mean ISS when the highest deformation is on the left, followed by the second-row middle seat.

3.2. Safest Seat for Children in Tomorrow's Cars

Table 3 presents major collision alert and collision mitigation technologies [26] that are likely to be present in L2+ AVs. Myriad studies have estimated the potential reduction in traffic crashes by ADAS features, and there are only a few studies that have evaluated the real-world effectiveness of these technologies in reducing crashes [27–31]. For example, AEB, along with forward collision warning (FCW), showed a 50% reduction in front-to-rear crash rates and a 56% reduction in front-to-rear injury crash rates [27]. The blind spot monitoring system showed a 14% reduction in lane-change crashes [28]. In a study by Brown et al. comparing vehicles with and without AEB, those equipped with AEB were found to reduce severe and minor injuries by 18 and 21%, respectively.

Table 3. Collision Alert and Mitigation Technologies in Vehicles.

Collision Alert	Collision Mitigation
Forward collision warning (FCW)	Forward automatic emergency braking (FAEB)
Lane departure warning (LDW)	Reverse automatic emergency braking (RAEB)
Blind spot warning (BSW)	Automatic emergency braking (AEB)
Rear cross-traffic warning (RCTW)	
Parking obstruction warning (POW)	
Pedestrian detection	

Using NASS GES data, the probabilities of a vehicle being impacted in different impact locations were estimated and are presented in Table 4. From the data, it is clear that vehicles are more likely to be impacted at the front than at other potential impact points. The probabilities of vehicles receiving an impact on either the left or right side are effectively the same.

Table 4. Frequencies and Probabilities of Involvement in Crashes by Impact Point.

Point of Impact	Frequency	Probabilities
Front	5,655,758	0.50
Back	2,978,093	0.26
Left	1,091,709	0.09
Right	389,597	0.10

If a vehicle equipped only with AEB is 50% effective in reducing frontal impacts, the probability of having a frontal impact reduces to 0.25 (0.50 $\times$ 0.50). In such vehicles, the probability of having an impact to the rear will be higher than that of an impact at the front. As AEB effectiveness increases, the front of the vehicle becomes much safer. With reverse AEB, the probability of having a rear impact will also decrease. Hence, Table 4 will not be valid for vehicles equipped with a single ADAS feature or a combination of ADAS features or for L2+ AVs.

In scenarios where AEB cannot prevent a crash, it will decrease the vehicle speed before colliding. As the impact speed decreases, the mean ISS values presented in Figure 2a (frontal impact) will decrease. Lane departure warning/prevention, blind spot monitoring, etc., will impact the mean ISSs presented in Figure 2b,d (left and right impact). Similarly, reverse AEB will influence the injury severities from a rear impact. Overall, it is reasonable to assume that all such reductions in injury severity will not be even across different seat positions.

Furthermore, the primary reason children are not recommended to sit in the front seat is due to the frequency of frontal impact collisions and airbag deployment injuries [32,33]. However, if AEB alone reduces the frequency of frontal collisions and decreases the impact speed that affects the activation of an airbag deployment, will the front seat still be dangerous in L2+ AVs? With the advent of advanced driver assistance systems (ADAS) that are likely to be present in the L2+ AVs, the injury severity for children will change. L2+ AVs will have lower injury severity outcomes and decreased probabilities of crashes than traditional vehicles. Therefore, assuming that the second-row middle seat will remain the safest seat in L2+ AVs might not be appropriate. Henceforth, it is essential to identify what will be the safest seat for children in L2+ AVs.

4. Discussion

In the future, the presence of children in AVs is a plausible scenario given the rapid progress of AV technology and the significant number of American adults who wish to have children or who have had children. While myriad studies have concentrated on AVs' safety and mobility benefits, few studies have tried to shed light on the topic of "children and automated vehicles". In a survey-based study, participants were more willing to send empty AVs to collect groceries rather than to pick up their children from school [34]. Lee and Mirman [35] found that mothers and parents with younger children were more concerned than their counterparts regarding AVs. In a driving simulator followed by a focus group study, "parents would require two-way audio communication and prefer video feeds of vehicle interiors, seat belt checks, automatic locking, secure passenger identification, and remote access to vehicle information" [36]. The primary concern parents expressed was the lack of protection in AVs during unplanned trip interruptions. Parents with children who reported using any child restraint system expressed more concern over potentially using AVs to transport their children.

However, the aforementioned studies mainly concentrated on parents' willingness to use AVs to transport children. One key aspect that has not been researched is where children should sit in AVs. Should they be sitting in the rear seats as they were doing in today's cars? This study, even though it does not identify the safest seat in L2+ AVs because of the data limitations, at least aims to shed light on this topic by demonstrating how injury severity could be different in L2+ AVs. This study shows a need for research in this area. Going forward, identifying the safest seat in L2+ AVs will be a challenging task for the following reasons:

- as advanced vehicle technologies have recently seen wider adoption, relatively fewer vehicles on roads are equipped with these technologies;
- as the crash rate is lower for vehicles equipped with advanced vehicle technologies, they will not appear in the crash data as frequently as traditional vehicles;
- publicly available crash data do not have information on the presence and activation of these systems in vehicles involved in crashes.

Furthermore, following the traditional approach (i.e., waiting for several years to aggregate crash data and analyzing them to identify the safest seat for children) might not be the best way to use the vehicle technology efficiently. Instead of being reactive, the safest seat position for children should be identified proactively. For example, it could be approached similarly to how NHTSA currently employs its 5-star safety rating program for vehicles. Vehicles and their safety technologies could be tested under specific simulations or near real-world conditions to examine children's injury severities in different seat positions. Injury severity outcomes could be compared across different seat positions and different crash conditions to identify the safest for children.

Because of the transition in the NASS data collection, the authors could not use the latest data for the analysis conducted. Even with the slightly older data, this study achieved its objectives and provided a basis for future research. Under the new NASS data collection system, information on the presence and activation of various advanced vehicle technologies is being collected. However, as this is sample data, not even a handful of vehicles involved had ADAS technologies present and activated. It is expected that this number will increase over the next few years as more and more vehicles with these technologies penetrate the market. As the next steps of this study, the authors will study how ADAS technologies and L2+ AVs affect injury severity for adults and children.

5. Conclusions

Based on research conducted two decades ago, the rear middle seat was identified as the safest position for children [12,13]. However, auto manufacturers have constantly been designing vehicles to improve the safety of occupants, which has the potential to influence the safest seat position in the vehicle. Because of the advancements in safety features, this study reassessed the safest seat position for children in current vehicles. The rear middle seat remained the safest seat for children in these vehicles.

Restraint use among children has increased to over 90% in the U.S. [37]. However, recent statistics still reveal that 37% of children who died in crashes are unrestrained [38]. Our results indicate that about 45% of children involved in crashes were not restrained. Thus, at the core of child safety, an excellent hands-on educational intervention is essential for parents/guardians to correctly apply car seats or booster seats [39,40]. Specifically, in terms of the average ISS values, we find that the use of a restraint effectively reduces the injury severity scores by at least 89% for different seat positions in a car for children. Therefore, using restraint systems (as appropriate for the child's age, height, and weight) is effective in reducing the injury severity for children involved in crashes. Similar findings have also been well documented in the literature [7,8,10]. In addition to the fact that our study findings of effective restraint systems align with previous findings, this study has also added to the body of knowledge on how the restraint system has a different effect for different seat positions coupled with four separate impact locations (i.e., front, right, left, back). Compared with older vehicles, newer vehicles have significantly improved safety performance in terms of the ISS values for children, particularly for the front right seat. Such an interesting finding was also disclosed in a study by Tatem and Gabler [18], where fatality risks in rear seats in the newest model year vehicles carry a higher fatality risk than in front seats. Using 2012–2016 South Australia data, Zhai et al. [41] further clearly indicate that the front passenger seat was the safest seat among all passenger seats. All of these results offer insightful indications that the previously perceived "dead seat"—the front passenger seat—is becoming safer in new model vehicles.

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References

1. Child Passenger Safety: Get the Facts. Available online: https://www.cdc.gov/transportationsafety/child_passenger_safety/cps-factsheet.html (accessed on 28 February 2023).
2. Durbin, D.R. Child passenger safety. *Pediatrics* **2011**, *127*, 1050–1066. [CrossRef] [PubMed]
3. Evans, L.; Frick, M.C. Seating position in cars and fatality risk. *Am. J. Public Health* **1988**, *78*, 1456–1458. [CrossRef] [PubMed]
4. Agran, P.; Castillo, D.; Winn, D. Comparison of motor vehicle occupant injuries in restrained and unrestrained 4–14 year olds. *Accid. Anal. Prev.* **1992**, *24*, 349–355. [CrossRef] [PubMed]

5. Huelke, D.F.; Compton, C.P. The effects of seat belts on injury severity of front and rear-seat occupants in the same frontal crash. *Accid. Anal. Prev.* **1995**, *27*, 835–838. [CrossRef] [PubMed]
6. Braver, E.R.; Whitfield, R.; Ferguson, S.A. Seating positions and children's risk of dying in motor vehicle crashes. *Inj. Prev.* **1998**, *4*, 181–187. [CrossRef]
7. Durbin, D.R.; Chen, I.; Smith, R.; Elliott, M.R.; Winston, F.K. Effects of Seating Position and Appropriate Restraint Use on the Risk of Injury to Children in Motor Vehicle Crashes. *Pediatrics* **2005**, *115*, e305–e309. [CrossRef]
8. Glass, R.J.; Segui-Gomez, M.; Graham, J.D. Child passenger safety: Decisions about seating location, airbag exposure, and restraint use. *Risk Anal.* **2000**, *20*, 521–528. [CrossRef]
9. Smith, K.M.; Cummings, P. Passenger seating position and the risk of passenger death or injury in traffic crashes. *Accid. Anal. Prev.* **2004**, *36*, 257–260. [CrossRef]
10. Lennon, A.; Siskind, V.; Haworth, N. Rear seat safer: Seating position, restraint use and injuries in children in traffic crashes in Victoria, Australia. *Accid. Anal. Prev.* **2008**, *40*, 829–834. [CrossRef]
11. Durbin, D.R.; Jermakian, J.S.; Kallan, M.J.; McCartt, A.T.; Arbogast, K.B.; Zonfrillo, M.R.; Myers, R.K. Rear seat safety: Variation in protection by occupant, crash and vehicle characteristics. *Accid. Anal. Prev.* **2015**, *80*, 185–192. [CrossRef]
12. Mayrose, J.; Priya, A. The safest seat: Effect of seating position on occupant mortality. *J. Saf. Res.* **2008**, *39*, 433–436. [CrossRef] [PubMed]
13. Kallan, M.J.; Durbin, D.R.; Arbogast, K.B. Seating patterns and corresponding risk of injury among 0- to 3-year-old children in child safety seats. *Pediatrics* **2008**, *121*, 1342–1347. [CrossRef] [PubMed]
14. Bliston, L.E.; Du, W.; Brown, J. A matched-cohort analysis of belted front and rear-seat occupants in newer and older model vehicles shows that gains in front occupant safety have outpaced gains for rear-seat occupants. *Accid. Anal. Prev.* **2010**, *42*, 1974–1977. [CrossRef] [PubMed]
15. Esfahani, E.S.; Digges, K. Trend of rear occupant protection in frontal crashes over model years of vehicles. *SAE Tech. Pap.* **2009**, 1–8. [CrossRef]
16. Sahraei, E.; Digges, K.; Marzougui, D. Reduced protection for belted occupants in rear-seats relative to front-seats of new model year vehicles. *Ann. Adv. Automot. Med.* **2010**, *54*, 149.
17. Sahraei, E.; Soudbakhsh, D.; Digges, K. Protection of rear-seat occupants in frontal crashes, controlling for occupant and crash characteristics. *SAE Tech. Pap.* **2009**, *53*, 75–91.
18. Tatem, W.M.; Gabler, H.C. Differential fatality risk between rear and front-seat passenger vehicle occupants in frontal crashes. In Proceedings of the 2019 International IRCOBI Conference on the Biomechanics of Injury, Florence, Italy, 11–13 September 2019.
19. Atkinson, T.; Gawarecki, L.; Tavakoli, M. Paired vehicle occupant analysis indicates age and crash severity moderate likelihood of higher severity injury in second row seated adults in frontal crashes. *Accid. Anal. Prev.* **2016**, *89*, 88–94. [CrossRef]
20. Mitchell, R.J.; Bambach, M.R.; Toson, B. Injury risk for matched front and rear-seat car passengers by injury severity and crash type: An exploratory study. *Accid. Anal. Prev.* **2015**, *82*, 171–179. [CrossRef]
21. NHTSA Announces Update to Historic AEB Commitment by 20 Automakers. Available online: https://www.nhtsa.gov/press-releases/nhtsa-announces-update-historic-aeb-commitment-20-automakers (accessed on 28 February 2023).
22. Driver Assistance Technologies. Available online: https://www.nhtsa.gov/equipment/driver-assistance-technologies#61996 (accessed on 28 February 2023).
23. National Automotive Sampling System. Available online: https://www.nhtsa.gov/crash-data-systems/national-automotive-sampling-system (accessed on 28 February 2023).
24. SAS Institute Inc. *SAS/STAT® 14.2 User's Guide: The SURVEYMEANS Procedure*; SAS: Cary, NC, USA, 2016.
25. Injury Severity Score. Available online: https://aci.health.nsw.gov.au/get-involved/institute-of-trauma-and-injury-management/data/injury-scoring/abbreviated_injury_scale (accessed on 28 February 2023).
26. Advanced Driver Assistance Technology Names. Available online: https://www.aaa.com/AAA/common/AAR/files/ADAS-Technology-Names-Research-Report.pdf (accessed on 28 February 2023).
27. Cicchino, J.B. Effectiveness of forward collision warning and autonomous emergency braking systems in reducing front-to-rear crash rates. *Accid. Anal. Prev.* **2017**, *99*, 142–152. [CrossRef]
28. Cicchino, J.B. Effects of blind spot monitoring systems on police-reported lane-change crashes. *Traffic Inj. Prev.* **2018**, *19*, 615–622. [CrossRef]
29. Sternlund, S.; Strandroth, J.; Rizzi, M.; Lie, A.; Tingvall, C. The effectiveness of lane departure warning systems—A reduction in real-world passenger car injury crashes. *Traffic Inj. Prev.* **2017**, *18*, 225–229. [CrossRef] [PubMed]
30. Cicchino, J.B. Effects of lane departure warning on police-reported crash rates. *J. Saf. Res.* **2018**, *66*, 61–70. [CrossRef] [PubMed]
31. Teoh, E.R. Effectiveness of Front Crash Prevention Systems in Reducing Large Truck Crash Rates. *Traffic Inj. Prev.* **2021**, *22*, 284–289. [CrossRef] [PubMed]
32. Quinones-Hinojosa, A.; Jun, P.; Manley, G.T.; Knudson, M.M.; Gupta, N. Airbag deployment and improperly restrained children: A lethal combination. *J. Trauma Acute Care Surg.* **2005**, *59*, 729–733.
33. Braver, E.R.; Ferguson, S.A.; Greene, M.A.; Lund, A.K. Reductions in deaths in frontal crashes among right front passengers in vehicles equipped with passenger air bags. *JAMA* **1997**, *278*, 1437–1439. [CrossRef]
34. Haboucha, C.J.; Ishaq, R.; Shiftan, Y. User preferences regarding autonomous vehicles. *Transp. Res. Part C Emerg. Technol.* **2017**, *78*, 37–49. [CrossRef]

35. Lee, Y.C.; Mirman, J.H. Parents' perspectives on using autonomous vehicles to enhance children's mobility. *Transp. Res. Part C Emerg. Technol.* **2018**, *96*, 415–431. [CrossRef]
36. Tremoulet, P.D.; Seacrist, T.; Ward McIntosh, C.; Loeb, H.; DiPietro, A.; Tushak, S. Transporting children in autonomous vehicles: An exploratory study. *Hum. Factors* **2020**, *62*, 278–287. [CrossRef]
37. Greenwell, N.K. Results of the National Child Restraint Use Special Study. No. DOT HS 812 142. 2015. Available online: https://trid.trb.org/view/1361381 (accessed on 7 May 2023).
38. Traffic Safety Facts, 2017 Data. Available online: https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812719 (accessed on 28 February 2023).
39. Tessier, K. Effectiveness of hands-on education for correct child restraint use by parents. *Accid. Anal. Prev.* **2010**, *42*, 1041–1047. [CrossRef]
40. Penmetsa, P.; Wang, T.; Nambisan, S. An Assessment of Child Restraint System Misuse in the United States. In Proceedings of the Transportation Research Board 97th Annual Meeting, Washington, DC, USA, 7–11 January 2018.
41. Zhai, G.; Yang, H.; Liu, J. Is the front passenger seat always the "death seat"? An application of a hierarchical ordered probit model for occupant injury severity. *Int. J. Inj. Control Saf. Promot.* **2020**, *27*, 438–446. [CrossRef]