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Incidence of Pedestrian and Bicyclist Crashes by Hybrid Electric Passenger Vehicles

Technical Report

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16. Abstract

Objective: This study examines the incidence rates of pedestrian and bicyclist crashes that involved hybrid electric vehicles (HEV) and to compare the results to internal combustion engine (ICE) vehicles under similar circumstances.

Methods: State crash files from NHTSA's State Data System were used to measure the incidence rates of pedestrian and bicyclist crashes by HEVs and to compare the incidence rate with their peer ICE vehicles.
The purpose of the study is to compare the crash experience of two different types of vehicles; it is not to make national estimates of problem size. The small sample size used in this study remains as a limitation towards conducting further analysis. Incidence rates provided in this report should be interpreted with caution due to the small sample size. Future analysis using larger sample size would provide better estimate of the problem size.

Results: This analysis was conducted on a total of 8,387 HEVs and 559,703 ICE vehicles that met the selection criteria. A total of 77 and 3,578 pedestrians were involved in crashes with HEVs and ICE vehicles, respectively. A total of 48 and 1,862 bicyclists were involved in crashes with HEVs and ICE vehicles, respectively.

This study found that pedestrian and bicyclist crashes involving both HEVs and ICE vehicles commonly occurred on roadways, in zones with low speed limits, during daytime and in clear weather, with higher incidence rates for HEVs when compared to ICE vehicles. A variety of crash factors were examined to determine the relative incidence rates of HEVs versus ICE vehicles in a range of crash scenarios. For one group of scenarios, those in which a vehicle is slowing or stopping, backing up, or entering or leaving a parking space, a statistically significant effect was found due to engine type. The HEV was two times more likely to be involved in a pedestrian crash in these situations than was an ICE vehicle. Vehicle maneuvers such as slowing or stopping, backing up, or entering or leaving a parking space, were grouped in one category based on that these maneuvers are potentially have occurred at very low speeds where the difference between the sound levels produced by the hybrid versus ICE vehicle is the greatest. In future analysis with a larger sample size, it would be ideal to investigate each of these maneuvers individually.
Incidence rate of pedestrian crashes in scenarios when vehicles make a turn was significantly higher for HEVs when compared to ICE vehicles. There was no statistically significant difference in incidence rate of pedestrian crashes involving HEVs when compared to ICE vehicles when both type of vehicles were going straight.

Similar to pedestrians, in crashes that potentially have occurred at very low speed such as when vehicles are turning, slowing, or stopping, backing up, or entering or leaving a parking space, the incidence rate of bicyclist crashes involving HEVs was significantly higher when compared to ICE vehicles. On a roadway was the most common location of bicyclist crashes involving both HEVs and ICE vehicles with no statistically significant difference. On the other hand, bicyclist crashes involving HEVs at intersections or interchanges were significantly higher when compared to ICE vehicles.

In conclusion, this study found that HEVs have a higher incidence rate of pedestrian and bicyclist crashes than do ICE vehicles in certain vehicle maneuvers. These results should serve as a guide when designing future HEVs pedestrian and bicyclist crash prevention programs. NHTSA will continue monitoring the incidence of pedestrian and bicyclist crashes involving HEVs. In future, a larger sample size would allow us to perform a more detailed analysis such as limiting the entire analysis to low-speed crashes, analyzing different vehicle maneuvers individually, etc. Data findings on this study will be updated when more recent State Data System and other data sources are available.

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EXECUTIVE SUMMARY

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This study found that pedestrian and bicyclist crashes involving both HEVs and ICE vehicles commonly occurred on roadways, in zones with low speed limits, during daytime and in clear weather, with higher incidence rates for HEVs when compared to ICE vehicles.

A variety of crash factors were examined to determine the relative incidence rates of HEVs versus ICE vehicles in a range of crash scenarios. For one group of scenarios, those in which a vehicle is slowing or stopping, backing up, or entering or leaving a parking space, a statistically significant effect was found due to engine type. The HEV was two times more likely to be involved in a pedestrian crash in these situations than was an ICE vehicle.

Vehicle maneuvers such as slowing or stopping, backing up, or entering or leaving a parking space were grouped in one category assuming these maneuvers have occurred at very low speeds where the difference between the sound levels produced by the hybrids versus ICE vehicles is the greatest. In future analysis with a larger sample size, it would be ideal to investigate each of these maneuvers individually.

Incidence rate of pedestrian crashes in scenarios when vehicles make turns was significantly higher for HEVs when compared to ICE vehicles. There was no statistically significant difference in incidence rate of pedestrian crashes involving HEVs when compared to ICE vehicles when both type of vehicles were going straight.

Similar to pedestrians, in crashes that occurred at very low speed, such as when a vehicle is making a turn, slowing or stopping, backing up, or entering or leaving a parking space, the incidence rate of bicyclist crashes involving HEVs was significantly higher when

compared to ICE vehicles. On a roadway was the most common location of bicyclist crashes involving both HEVs and ICE vehicles with no statistically significant difference. On the other hand, bicyclist crashes involving HEVs at intersections or interchanges were significantly higher when compared to ICE vehicles.

In conclusion, this study found that HEVs have a higher incidence rate of pedestrian and bicyclist crashes than do ICE vehicles in certain vehicle maneuvers. These results should serve as a guide when designing future HEVs' pedestrian and bicyclist crash prevention programs. NHTSA will continue monitoring the incidence of pedestrian and bicyclist crashes involving HEVs. In future, a larger sample size would allow us to perform a more detailed analysis, such as limiting the entire analysis to low-speed crashes, analyzing different vehicle maneuvers individually, etc. Data findings on this study will be updated when new State Data System and other data sources become available.

INTRODUCTION

Hybrid electric vehicles first became available to consumers in 2000 and are gaining popularity. Nationwide registrations for new HEVs rose to 350,289 in 2007, a 38-percent increase from 2006, according to R. L. Polk & Co.[4]

An HEV has a conventional engine (gasoline or diesel) as well as a large battery and an electric motor, so that the wheels of the vehicle are powered by both an internal combustion engine and an electric motor.[1] Different hybrid vehicles have different strategies for handling the electric motor and the internal combustion engine. According to Toyota's Web site, how the internal combustion engine in the Toyota Prius is used in certain situations depends upon the state of charge of the vehicle batteries, the temperature of the engine, the level of acceleration requested by the driver, and other factors.[7]

Advocacy groups have raised pedestrian safety concerns for HEVs. Their concern is that HEVs seem relatively quieter and may not emit the sounds that pedestrians and bicyclists rely on for warning as vehicle approaches them on the street or at an intersection.

In addition to the hypothesized higher risk of pedestrian crashes, the National Federation of the Blind, an advocacy group, is concerned that these "quieter cars" are a danger to blind pedestrians. Blind and visually impaired pedestrians rely on hearing an approaching vehicle to judge the vehicle's speed and proximity while navigating intersection crosswalks and other traffic situations.[5]

This paper aims to identify the crash incidence rates for pedestrians and bicyclists involving HEVs under different circumstances and to compare the results to ICE vehicles.

The crash data used for this study does not provide information on pedestrian vision status; therefore, the results on this study are provided for all pedestrians regardless of their vision status.

The purpose of the study is to compare the crash experience of two different types of vehicles; it is not to make national estimates of problem size. The small sample size used in this study remains as a limitation towards conducting further analysis. Future analysis using larger sample size would provide better estimate of the problem size.

METHODS AND DATA SOURCE

State crash files in the State Data System were used to measure the incidence rates of pedestrian and bicyclist crashes by HEVs and to compare the incidence rates with their peer ICE vehicles. Since the early 1980s, the National Highway Traffic Safety Administration has been obtaining from various States computer data files coded from data recorded on police accident reports (PARs). A PAR is completed by a police officer and contains information describing characteristics of the crash, the vehicles, and the people involved.

The rationales for using the State Data System include the following:

- The SDS includes all police-reported crashes, regardless of the injury or crash outcomes (large number of cases for comparison);
- The SDS contains Vehicle Identification Numbers (VINs) that identify the vehicle type (HEVs versus ICE vehicles). This study uses data from 12 States that provided VINs.
- The purpose of the study is to compare the crash experience of two different types of vehicles; it is not to make national estimates of problem size. If the hypothesized relationship exists across a wide variety of States, there is a reason to believe that it would hold across the entire country.

This study compares HEV and ICE passenger vehicles of model year 2000 and later. VINs are not provided by all States. Twelve State files (States that provided VINs) were used. HEVs were identified through the first 12 characters of the VIN. Each vehicle manufacturer has provided a unique method to identify HEVs according to certain VIN criteria. Vehicles with unknown or invalid VINs were excluded from the analysis. Incidences rates of pedestrian and bicyclist crashes reflect the "first harmful event" in the crash. The first harmful event indicates the first event to cause injury or damage in the crash.

Data analysis for each individual State was conducted, followed by aggregation of the results obtained from different States included in the analysis by using common data fields, such as lighting conditions during the crash, vehicle maneuvering prior to the crash, etc. Data reporting from States is not uniform. Some States do not report certain data fields. Numbers of cases in certain data fields that have not been reported by States or reported as unknown are noted under each table throughout this report.

Incidence rates were calculated as the number of vehicles of a given type involved in crashes with pedestrians or bicyclists under certain scenarios, divided by the total number of that type of vehicle that were in any crashes under the same scenarios. For example, if 56 HEVs were involved in pedestrian crashes during daytime and the total number of HEVs that have been in any crashes during daytime is 6,424; then the incidence rate of pedestrian crashes by HEVs during daytime is 56/6,424 X 100 or 0.9 percent.

In this analysis it was critical to control for vehicle speed. However, due to the fact that vehicle travel speed is not reliably reported in most police accident reports, we used zone the speed limit as a proxy for vehicle travel speed prior to the crash. A speed limit of 35 mph was used as a cut-off; pedestrian and bicyclist crashes were examined at speed limits less than or equal to 35 mph versus speed limits greater than 35 mph. In addition to speed limits, the vehicle maneuver prior to the crash was examined as in some cases the zone speed limit would not reflect the actual vehicle speed, for example when a vehicle starts from a stopped position in a zone with a higher speed limit.

The characteristic of the wind noise of a passenger vehicle depends on its shape, cruising speed, wind direction towards the car and the natural wind condition. Of these factors, the shape is the most important and the only controllable factor for the wind noise[6]. To

control for the wind noise effect and tire noise as a function of vehicle size, two comparable groups of HEVs and ICE vehicles were selected for analysis (case versus control). The HEVs (case group) selected were the Toyota Corolla, Toyota Camry, Toyota Prius, Honda Civic, and Honda Accord. The ICE vehicles (control group) selected are the Toyota Corolla, Toyota Camry, Honda Civic, and Honda Accord. The analysis is limited to vehicles of model year 2000 and later. The Honda Insight was considered but excluded from the analysis due to the fact that the earlier model years of Honda Insight always operate using their internal combustion engines, even at low speed.

Weather conditions such as rain, snow, fog, and smog restrict drivers' and pedestrians' ability to see.[2] Road darkness would lead to a significant increase in the probability of a pedestrian fatal injury.[2] To control for the variations on pedestrian crashes due to light and weather conditions, this study provides detailed analysis of light and weather conditions during the crashes.

The State Data System does not include information on pedestrian vision status. This analysis provides data on pedestrian crashes by HEVs regardless of pedestrian vision status. The data analysis results are provided in two different sections for pedestrians and bicyclists.

Both descriptive and inferential analyses were conducted to measure the incidence rates of pedestrian and bicyclist crashes by HEVs and to compare the results with counterpart ICE vehicles.

This study is exploratory in nature and aims to guide researchers when designing pedestrian and bicyclist crash prevention research.

Results that are statistically significant will be indicated by using an asterisk (*) throughout the report.

RESULTS: OVERVIEW OF DATA USED IN THE STUDY

As shown in Table 1, 12 States were used in the analysis. The data availability years varied across different States. Seven States had data available through 2006.

Table 1: States included in the analysis

State	Years Available
Alabama	2000 to 2006
Florida	2002 to 2007
Georgia	2000 to 2006
Illinois	2000 to 2005
Kansas	2001 to 2006
Maryland	2000 to 2007
Michigan	2004 to 2006
New Mexico	2001 to 2006
North Carolina	2000 to 2006
Pennsylvania	2000 to 2005
Washington	2002 to 2005
Wisconsin	2000 to 2006

This analysis was conducted on a total of 8,387 HEVs vehicles and 559,703 ICE vehicles that met the selection criteria. A total of 77 and 3,578 pedestrians were involved in crashes with HEVs and ICE vehicles, respectively. A total of 48 and 1,862 bicyclists were involved in crashes with HEVs and ICE vehicles, respectively (Table 2).

Table 2: Cases included in the analysis

Cases Included in the Study	HEVs	ICE Vehicles
Total Number of Vehicles Included in analysis	8,387	559,703
Pedestrians involved in crashes	77	3,578
Bicyclists involved in crashes	48	1,862

Some variables used in this study are not reported by all States. Tables 3a through 3e provide numbers of HEVs and ICE vehicles that are included in the analysis under different crash circumstances.

Table 3a: Speed Limit at crash location

Speed	HEVs	Percent	ICE Vehicles	Percent
<= 35 mph	2,609	31%	152,833	27%
> 35 mph	3,101	37%	185,356	33%
Unknown	2,677	32%	221,514	40%
Total	**8,387**	**100%**	**559,703**	**100%**

Table 3b: Lighting condition during the crash				
Light Condition	**HEVs**	**Percent**	**ICE Vehicles**	**Percent**
Daylight	6,424	77%	413,332	74%
Dark—street lights on	1,029	12%	83,094	15%
Dark—no lights	558	7%	39,658	7%
Dawn/dusk	296	4%	19,463	3%
Other	9	<1%	400	<1%
Unknown	71	1%	3,756	1%
Total	**8,387**	**100%**	**559,703**	**100%**

Table 3c: Location of the crash				
Location	**HEVs**	**Percent**	**ICE Vehicles**	**Percent**
On roadway	4,342	52%	318,118	57%
Intersection/Interchange	1,194	14%	70,541	13%
Off roadway including parking lot	594	7%	57,578	10%
Other	199	2%	16,960	3%
Unknown	2,058	25%	96,506	17%
Total	**8,387**	**100%**	**559,703**	**100%**

Table 3d: Vehicle maneuver prior to crash				
Vehicle Maneuver	**HEVs**	**Percent**	**ICE Vehicles**	**Percent**
Going straight	3,667	44%	261,522	47%
Making a turn	1,061	13%	70,245	13%
Slowing/stopping	1,137	14%	70,872	13%
Backing	132	2%	9,093	2%
Entering/leaving parking space/driveway	83	1%	5,870	1%
Starting in traffic	102	1%	4,168	1%
Other	2,079	25%	131,715	24%
Unknown	126	2%	6,218	1%
Total	**8,387**	**100%**	**559,703**	**100%**

Table 3e: Weather Condition during the crash				
Weather Condition	**HEVs**	**Percent**	**ICE Vehicles**	**Percent**
Clear	5,467	65%	373,667	67%
Cloudy/foggy	1,078	13%	78,598	14%
Raining	784	9%	64,061	11%
Snowing	172	2%	10,024	2%
Other	213	3%	8,257	1%
Unknown	673	8%	25,096	4%
Total	**8,387**	**100%**	**559,703**	**100%**

RESULTS: PEDESTRIAN CRASHES

A total of 77 HEV vehicles were involved in crashes with pedestrians, accounting for 0.9 percent of all HEVs included in the analysis. A total of 3,578 ICE vehicles were involved in crashes with pedestrians, accounting for 0.6 percent of all ICE vehicles included in the analysis. The difference in the incidence rates of pedestrian crashes between HEVs and ICE vehicles was statistically significant at the 0.05 level [OR: 1.4 and *p*-value: 0.002] (Table 4).

Table 4: Pedestrian crashes HEVs vs. ICE vehicles

					95% Confidence Intervals	
	HEVs	**ICE Vehicles**	**Odds Ratio**	***p*-value**	**Lower**	**Upper**
Pedestrian Crashes (*)	**77 (0.9%)**	**3,578 (0.6%)**	**1.4**	**0.002**	**1.1**	**1.8**

Zone Speed Limit

In most cases, a vehicle's actual travel speed prior to the crash is unknown. Therefore, the zone speed limit was used as a proxy for vehicle travel speed. Overall, most pedestrian crashes involving both HEVs and ICE vehicles occurred in zones with speed limit less than 35 mph.

As shown in Tables 5 and 3a, of the 2,609 HEVs that were involved in crashes while traveling in a speed zone of 35 mph or less, 48 of these vehicles involved pedestrian crashes at an incidence rate of 1.8 percent. Of the 152,833 ICE vehicles that were traveling in zones of 35 mph or less, 1,836 of these vehicles involved pedestrian crashes at an incidence rate of 1.2 percent. The difference in incidence rate of pedestrian crashes at zone speed limit of 35 mph or less between HEVs and ICE vehicles was statistically significant at the 0.05 level [OR: 1.5 and *p*-value: 0.003].

Table 5: Speed limit during pedestrian crashes HEVs vs. ICE vehicles

Speed Limit	**Pedestrian count- HEVs**	**Incidence rate of pedestrian crashes - HEVs**	**Pedestrian count - ICE vehicles**	**Incidence rate of pedestrian crashes -ICE vehicles**
<= 35 mph (*)	48	1.8%	1,836	1.2%
> 35 mph	8	0.3%	601	0.3%
Total	**56**	**1.0%**	**2,437**	**0.7%**

Zone speed limit is unknown or not reported for 21 HEVs and 1,141 ICE vehicles

Vehicle Maneuver

Going straight is the most common vehicle maneuver prior to pedestrian crashes for both HEVs and ICE vehicles. Incidence rate of pedestrian crashes while the vehicle was going straight was 0.9 percent and for HEVs and 0.8 percent for ICE vehicles with no significant difference at the 0.05 level [OR: 1.1 and *p*-value 0.46].

Making a turn was the second most common vehicle maneuver prior to pedestrian crashes for both HEVs and ICE vehicles. Of the 1,061 HEVs that were making turns prior to crashes, a total of 19 pedestrians were identified as involved in the first harmful

event in the crash at an incidence rate of 1.8 percent. A total of 70,245 ICE vehicles included in this analysis were making turns prior to crashes. Of that total, 698 involved pedestrians in the first harmful event at an incidence rate of 1.0 percent. The difference in incidence of pedestrian crashes between HEVs and ICE vehicles when the vehicle makes a turn prior to the crash was statistically significant at the 0.05 level [OR: 1.8 and *p*-value: 0.001].

Table 6a: Vehicle maneuver prior to pedestrian crashes HEVs vs. ICE vehicles

Vehicle Maneuver	Pedestrian count - HEVs	Incidence rate of pedestrian crashes - HEVs	Pedestrian count - ICE vehicles	Incidence rate of pedestrian crashes - ICE vehicles
Going straight	33	0.9%	2,069	0.8%
Making a turn (*)	19	1.8%	698	1.0%
Slowing/stopping	6	0.5%	148	0.2%
Backing	7	5.3%	261	2.9%
Entering/leaving parking space/driveway	1	1.2%	55	0.9%
Starting in traffic	3	2.9%	50	1.2%
Other	6	0.3%	238	0.2%
Total	**75**	**0.9%**	**3,519**	**0.6%**

Vehicle maneuver is unknown or not reported for 2 HEVs and 59 ICE-vehicles

Incidence rate of pedestrian crashes that potentially have occurred at very low speed such as when a vehicle is slowing or stopping, backing up, or entering or leaving a parking space was significantly higher among HEVs when compared to ICE vehicles. A total of 1,454 HEVs were engaged in one of these maneuvers prior to the crashes; of them 17 vehicles involved pedestrians as the first harmful event at an incidence rate of 1.2 percent. On the other hand, a total of 90,003 ICE vehicles were engaged in one of these maneuvers prior to the crashes; of them 514 vehicles involved pedestrians as the first harmful event at an incidence rate of 0.6 percent. The difference between pedestrian crashes involving HEV and ICE vehicles was statistically significant at the 0.05 level as indicated by OR: 2.1 and *p*-value 0.003 (Table 6b).

Table 6b: Pedestrian crashes at potentially very low speed maneuvers

Vehicle Maneuver	HEVs Pedestrian Crashes	Total # HEVs	ICE Vehicles/ Pedestrian Crashes	Total # ICE Vehicles
Slowing/stopping	6	1,137	148	70,872
Backing	7	132	261	9,093
Entering/leaving parking space/driveway	1	83	55	5,870
Starting in traffic	3	102	50	4,168
Total (*)	**17 (1.2%)**	**1,454**	**514 (0.6%)**	**90,003**

Pedestrian crashes HEVs : ICE Vehicles OR: 2.1 *p*-value 0.003

Crash Location

On a roadway was the most common location where pedestrian crashes occurred for both HEVs and ICE vehicles. Of the 4,342 HEVs that were involved in crashes on roadways,

29 of them involved pedestrians in the first harmful event of the crash at an incidence rate of 0.7 percent. Of the 318,118 ICE vehicles that were involved in crashes on roadways, 1,413 of them involved pedestrians in the first harmful event of the crash at an incidence rate of 0.4 percent. The difference between the incidence rate of pedestrian crashes on roadways involving either HEVs or ICE vehicles was statistically significant at the 0.05 level [OR: 1.5 and *p*-value: 0.04] (Tables 7 and 3c).

Table 7: Location of pedestrian crashes

Location of Crash	Pedestrian count- HEVs	Incidence rate of pedestrian crashes - HEVs	Pedestrian count - ICE vehicles	Incidence rate of pedestrian crashes - ICE vehicles
On roadway (*)	29	0.7%	1,413	0.4%
Intersection/Interchange	9	0.8%	392	0.6%
Off roadway including parking lot	7	1.2%	418	0.7%
Other	1	0.5%	80	0.5%
Total	**46**	**0.7%**	**2,303**	**0.5%**

Crash location is unknown or not reported for 31 HEVs and 1,275 ICE-vehicles

Lighting Condition

Lighting condition during the crash was examined to identify if the visibility of the HEVs during dark conditions relative to the ICE vehicles would affect the incidence of pedestrian crashes. The majority of pedestrian crashes by either HEVs or ICE vehicles occurred in daylight. Of the 6,424 hybrid vehicles that were involved in crashes during daytime, 56 of them involved pedestrians at an incidence rate of 0.9 percent. Of the 413,332 ICE vehicles that were involved in crashes, 2,469 involved pedestrians at an incidence rate of 0.6 percent. The difference of the incidence rate of pedestrian crashes by HEVs and ICE vehicles was statistically significant at the 0.05 level [OR: 1.5; *p*-value 0.005]. Incidence rate of pedestrian crashes by HEVs was higher during dawn or dusk and when streets are dark with no street lights. However, due to the small cell counts on hybrid vehicles, a test for significance was not performed (Tables 8 and 3b).

Table 8: Light condition during pedestrian crashes

Light Condition	Pedestrian count - HEVs	Incidence rate of pedestrian crashes - HEVs	Pedestrian count - ICE vehicles	Incidence rate of pedestrian crashes - ICE vehicles
Daylight (*)	56	0.9%	2,469	0.6%
Dark—street lights on	12	1.2%	717	0.9%
Dark—no lights	6	1.1%	278	0.7%
Dawn/dusk	3	1.0%	91	0.5%
Other	0	0%	2	0.5%
Total	**77**	**0.9%**	**3,557**	**0.6%**

Light condition is unknown or not reported for 21 ICE-vehicles

Weather Condition

Pedestrian crashes commonly occur during clear weather regardless of vehicle type. As shown in Tables 9 and 3e, a total of 5,467 HEVs were involved in crashes during clear weather; 50 of these vehicles involved pedestrians at an incidence rate of 0.9 percent. On the other hand, of the 373,667 ICE vehicles that were involved in crashes, 2,566 involved pedestrians in the first harmful event at an incidence rate of 0.8 percent. The difference in incidence rate of pedestrian crashes between HEVs and ICE vehicles during clear weather was statistically significant at the 0.05 level [OR: 1.3; *p*-value: 0.04]. Incidence rate of pedestrian crashes by HEVs when it was raining, snowing, cloudy, or foggy was higher compared to ICE vehicles. However, due to small sample size on HEVs, a test for significance was not performed.

Table 9: Weather condition during pedestrian crashes

Weather Condition	Pedestrian count - HEVs	Incidence rate of pedestrian crashes - HEVs	Pedestrian count - ICE vehicles	Incidence rate of pedestrian crashes - ICE vehicles
Clear (*)	50	0.9%	2,566	0.8%
Cloudy/foggy	7	0.7%	372	0.6%
Raining	11	1.4%	402	0.7%
Snowing	2	1.2%	58	0.7%
Other	3	1.4%	43	0.6%
Total	**73**	**1.0%**	**3,441**	**0.7%**

Weather condition is unknown or not reported for 4 HEVs and 137 ICE-vehicles

RESULTS: BICYCLIST CRASHES

A total of 48 HEVs were involved in crashes with bicyclists, accounting for 0.6 percent of all HEV crashes included in this analysis. A total of 1,862 ICE vehicles were involved in crashes with bicyclists, accounting for 0.3 percent of all ICE vehicles included in this analysis. The difference in the incidence rate of bicyclist crashes between HEVs and ICE vehicles was statistically significant at the 0.05 level as indicated by an odds ratio of 1.7 and *p*-value of 0.0002 (Table 10).

Table 10: Bicyclist Crashes HEVs versus ICE Vehicles

					95% Confidence Intervals	
	HEVs	ICE-Vehicles	Odds Ratio	*p*-value	Lower	Upper
Bicyclist Crashes (*)	**48 (0.6%)**	**1,862 (0.3%)**	**1.7**	**0.0002**	**1.3**	**2.3**

Zone Speed Limit

Overall most bicyclist crashes involving both HEVs and ICE vehicles occurred in low-speed-limit zones. As shown in Tables 11 and 3a, of the 2,609 hybrid vehicles that were traveling in speed zones of 35 mph or less, 25 of them involved bicyclist crashes at an incidence rate of 1.0 percent. On the other hand of the 152,833 ICE vehicles involved in crashes in speed zones of 35 mph or less, 963 vehicles involved bicyclist crashes at an incidence rate of 0.6 percent. The difference in incidence of bicyclist crashes at zone

speed limits of 35 mph or less between HEV and ICE vehicles was statistically significant at the 0.05 level [OR: 1.5 and *p*-value: 0.04].

Table 11: Zone speed limit at the crash location

Speed Limit	Bicyclist count - HEVs	Incidence rate of bicyclist crashes - HEVs	Bicyclist count - ICE vehicles	Incidence rate of bicyclist crashes - ICE vehicles
<= 35 mph (*)	25	1.0%	963	0.6%
> 35 mph	9	0.3%	314	0.2%
Total	**34**	**0.6%**	**1,277**	**0.4%**

Zone speed limit is unknown or not reported for 14 HEVs and 585 ICE vehicles

Vehicle Maneuver

Most bicyclist crashes in this analysis by HEVs and ICE vehicles occurred while the vehicles were going straight. The difference in incidence rate of bicyclist crashes between HEVs and ICE vehicles while the vehicles were going straight was statistically significant at the 0.05 level [OR: 1.8 and *p*-value 0.006] (Table 12).

Table 12a: Vehicle maneuver prior to pedalcyclist crashes

Vehicle maneuver	Bicyclist count - HEVs	Incidence rate of bicyclist crashes - HEVs	Bicyclist count - ICE vehicles	Incidence rate of bicyclist crashes - ICE vehicles
Going straight (*)	22	0.6%	873	0.3%
Making a turn	14	1.3%	659	0.9%
Slowing/stopping	3	0.3%	101	0.1%
Backing	0	0%	21	0.2%
Entering/leaving parking space/driveway	3	3.6%	20	0.3%
Starting in traffic	1	1.0%	38	0.9%
Other	5	0.2%	129	0.1%
Total	**48**	**0.6%**	**1,841**	**0.3%**

Vehicle maneuver is unknown or not reported for 21 ICE vehicles

Incidence rate of a bicyclist crash that potentially has occurred at very low speed such as when a vehicle makes a turn, slows or stops, backs up, or enters or leaves a parking space was significantly higher among HEVs when compared to ICE vehicles. A total of 2,515 HEVs that were engaged in one of these maneuvers prior to the crashes, 21 crashes involved bicyclists as the first harmful event at an incidence rate of 0.8 percent. On the other hand, a total of 160,248 ICE vehicles were engaged in one of these maneuvers prior to the crashes; of them 839 vehicles involved bicyclists as first harmful event at an incidence rate of 0.5 percent. The difference between bicyclist crashes involving HEVs and ICE vehicles was statistically significant at the 0.05 level as indicated by OR: 1.6 and *p*-value 0.03 (Table 12b).

Table 12b: Bicyclist crashes at potentially very low speed maneuvers				
Vehicle Maneuver	**HEVs/bicyclist crashes**	**Total # HEVs**	**ICE Vehicles/ bicyclist crashes**	**Total # ICE vehicles**
Making a turn	14	1,061	659	70,245
Slowing/stopping	3	1,137	101	70,872
Backing	0	132	21	9,093
Entering/leaving parking space/driveway	3	83	20	5,870
Starting in traffic	1	102	38	4,168
Total (*)	**21 (0.8%)**	**2,515**	**839 (0.5%)**	**160,248**
Bicyclist crashes HEVs : ICE Vehicles OR: 1.6 *p*-value 0.03				

Crash Location

On the roadway was the most common location where bicyclist crashes occurred for both HEVs and ICE vehicles. Of the 4,342 HEVs that were involved in crashes on the roadway, 17 of them were involving bicyclists in the first harmful event of the crash at an incidence rate of 0.4 percent. Of the 318,118 ICE vehicles that were involved in crashes on roadways, 782 of them involved bicyclists in the first harmful event of the crash at an incidence rate of 0.2 percent. The difference between the incidence rate of bicyclist crashes on roadways involving either HEVs or ICE vehicles was not statistically significant at the 0.05 level [OR: 1.6 and *p*-value: 0.06].

The incidence rate of bicyclist crashes involving HEVs at intersections or interchanges was 1.3 percent compared to 0.7 percent for ICE vehicles. The difference in incidence rate of bicyclist crashes at intersections or interchanges was statistically significant at the 0.05 level for HEVs when compared to ICE vehicles [OR: 1.8; p-value 0.01] (Tables 13 and 3c).

Table 13: Location of bicyclist crashes				
Location of Crash	**Bicyclist count - HEVs**	**Incidence rate of bicyclist crashes - HEVs**	**Bicyclist count - ICE vehicles**	**Incidence rate of bicyclist crashes - ICE vehicles**
On roadway	17	0.4%	782	0.2%
Intersection/Interchange (*)	16	1.3%	513	0.7%
Off roadway including parking lot	5	0.8%	198	0.3%
Other	2	1.0%	55	0.3%
Total	**40**	**0.6%**	**1,548**	**0.3%**
Location of crash is unknown or not reported for 8 HEVs and 314 ICE vehicles				

Lighting Condition

The majority of bicyclist crashes by either HEVs or ICE vehicles occurred in daylight. As noted in Table 14, incidence rate of bicyclist crashes involving HEVs was statistically significantly higher (0.6%) during daylight when compared to ICE vehicles (0.4%) [OR: 1.8; *p*-value 0.0003].

Table 14: Light condition during pedalcyclist crashes				
Light Condition	**Bicyclist count - HEVs**	**Incidence rate of bicyclist crashes - HEVs**	**Bicyclist count - ICE vehicles**	**Incidence rate of bicyclist crashes - ICE vehicles**
Daylight (*)	41	0.6%	1,500	0.4%
Dark—street lights on	5	0.5%	205	0.2%
Dark—no lights	1	0.2%	72	0.2%
Dawn/dusk	1	0.3%	79	0.4%
Other	0	0%	1	0.3%
Total	**48**	**0.6%**	**1,857**	**0.3%**
Lighting condition is unknown or not reported for 5 ICE vehicles				

Weather Condition

Bicyclist crashes commonly occur during clear weather regardless of vehicle type. As shown in Table 15, 40 (87%) and 1,402 (81%) of bicyclist crashes occurred in clear weather for HEVs and ICE vehicles, respectively.

Table 15: Weather condition during pedalcyclist crashes				
Weather Condition	**Bicyclist count - HEVs**	**Incidence rate of bicyclist crashes - HEVs**	**Bicyclist count - ICE vehicles**	**Incidence rate of bicyclist crashes - ICE vehicles**
Clear (*)	40	0.7%	1,402	0.4%
Cloudy/Foggy	3	0.3%	200	0.3%
Raining	3	0.4%	93	0.1%
Snowing	0	0%	9	0.1%
Other	0	0%	25	0.3%
Total	**46**	**0.6%**	**1,729**	**0.3%**
Weather condition is unknown or not reported for 2 HEVs and 133 ICE vehicles				

CONCLUSION AND DISCUSSION

This analysis was conducted on a total of 8,387 HEVs and 559,703 ICE vehicles that met the selection criteria. A total of 77 and 3,578 pedestrians were involved in crashes with HEVs and ICE vehicles, respectively. A total of 48 and 1,862 bicyclists were involved in crashes with HEVs and ICE vehicles, respectively.

This study found that pedestrian and bicyclist crashes involving both HEVs and ICE vehicles commonly occurred on roadways, in zones with low speed limits, during daytime, and in clear weather, with higher incidence rates for HEVs when compared to ICE vehicles.

A variety of crash factors were examined to determine the relative incidence rates of HEVs versus ICE vehicles in a range of crash scenarios. For one group of scenarios, those in which a vehicle is slowing or stopping, backing up, or entering or leaving a parking space, a statistically significant effect was found due to engine type. The HEV was two times more likely to be involved in a pedestrian crash in these situations than was an ICE vehicle.

Vehicle maneuvers such as slowing or stopping, backing up, or entering or leaving a parking space, were grouped in one category because these maneuvers potentially occurred at very low speeds where the difference between the sound levels produced by the hybrid versus ICE vehicle is the greatest. In future analysis with a larger sample size, it would be ideal to investigate each of these maneuvers individually.

Incidence rate of pedestrian crashes in scenarios when a vehicle makes a turn was significantly higher for HEVs when compared to ICE vehicles. There was no statistically significant difference in incidence rate of pedestrian crashes involving HEVs when compared to ICE vehicles when both types of vehicles were going straight.

Similar to pedestrians, in a crash that occurred at very low speed such as when a vehicle is making a turn, slowing or stopping, backing up, or entering or leaving a parking space, the incidence rate of bicyclist crashes involving HEVs was significantly higher when compared to ICE vehicles. On the roadway was the most common location of bicyclist crashes involving both HEVs and ICE vehicles with no statistically significant difference. On the other hand, bicyclist crashes involving HEVs at intersections or interchanges were significantly higher when compared to ICE vehicles.

In conclusion, this study found that HEVs have a higher incidence rate of pedestrian and bicyclist crashes than do ICE vehicles in certain vehicle maneuvers. These results should serve as a guide when designing future HEV pedestrian and bicyclist crash prevention programs. NHTSA will continue monitoring the incidence of pedestrian and bicyclist crashes involving HEVs. In the future, a larger sample size would allow us to perform a more detailed analysis such as limiting the entire analysis to low-speed crashes, analyzing different vehicle maneuvers individually, etc. Data findings on this study will be updated when newer State Data System and other data sources become available.

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