TITLE: A pilot analysis of crash severity of electric passenger cars in Spain (2016-2020)

INTRODUCTION

At the end of march 2022, there were 169,741 battery and plug-in electric vehicles in Spain. These electric vehicles (EV) accounted for almost 12% of all new registered vehicles and 0.65% of the vehicle fleet in 2022 (year-to-date) (EAFO, 2022). Although these figures are far from the fleet of electric vehicles in other European countries like Germany, Sweden or France (note that for the European countries that belong to the European Union, the average market share of new vehicles was around 18% in 2021), there is an increasing trend of replacing internal combustion engine (ICE) vehicles with EV. This shift towards cleaner vehicles is encouraged by the mobility policies of the European Union that promote more sustainable modes of transport with a target of reaching between 16% and 35% of clean cars in the EU fleet by 2025 (European Commission, 2019).

There are three major types of EV according to the degree of electrification used: hybrid electric vehicles (HEV) are powered by the conventional internal combustion engine and an electromotor that uses energy from batteries that are charged by the ICE; plug-in hybrid vehicles (PHEV), powered by conventional ICE and an electromotor that uses energy from batteries that are recharged from the power grid; and battery electric vehicles (BEV), which are propelled by electro-motors using the energy of on-board batteries charged from the power grid. In the three cases, there is a battery pack that that either supplements or completely replaces the ICE. Although there is a variety of hybrid technologies within the PHEV group in the market, all vehicles within this category share one common characteristic: the existence of a larger battery pack (compared to non-plug in hybrid cars) that is charged directly from the power grid. For the purpose of this work, PHEV and BEV will be combined into just one category: electric vehicles (EV).

While the main difference between ICE vehicles and EV is the reduction in contaminating emissions, the structural design of EV, with an increased weight due to the battery pack, a different distribution of load-bearing structures, and the potential behavioral differences in driving styles of EV owners, together with a more dedicated use of EV in urban areas, likely influence the crash experience of EV occupants and make it different from that of ICE vehicle occupants. These differences can be especially important in the case of BEV as the absence of the engine can allow for structural components providing improved crashworthiness.

This pilot study analyzes real-world collision data in Spain between 2016 and 2020 to explore whether the risk of sustaining fatal or severe injuries in an EV is similar to that of an ICE vehicle.

METHODS

Collision data were obtained from the General Directorate for Traffic (DGT) of the Ministry of Interior of Spain. The data include every collision involving at least one motor vehicle and one injured person and it is available from the DGT under request. The data are collected by police forces that attend to the victims after the crash and collect the necessary information to understand the concurrent factors that contributed to the collision, with a focus on legal aspects and potential infractions. Thus, DGT data are not specifically designed for research or policy assessment. However, the data system is close to be a census of all collisions with injuries in Spain.

The first crash involving a EV car in Spain occurred in 2014 and, at the time of drafting this manuscript, the last year with available information was 2020. In addition to the type of propulsion of the vehicle, other variables included in the study were whether all occupants in the vehicle used the seat belt; the number of fatalities and severely injured occupants per vehicle; the location of the crash (urban, inter-urban); the car model year; and the main impact direction of the collision. Spanish DGT data considers a fatal injury when death occurs within 30 days of the collision and a serious injured occupant is defined as an occupant that requires hospital admission for more than 24 hours.

This study includes preliminary descriptive analyses to understand whether EV and ICE vehicles occupants are exposed to similar injury risks in case of participating in a crash. When relevant, the 95% confidence interval (CI) for a proportion is included. Some of the analyses were restricted to frontal impacts to ensure that the collision characteristics were comparable between ICE vehicles and EV.

RESULTS

As shown in Figure 1, the number of EV crashes has increased over the last five years in Spain up to 2020, in which the effects of the mobility restrictions of the COVID-19 pandemic reduced the number of trips and also the exposure to risk. These results are also included in Table 1, which also shows a similar trend for the crashes involving ICE vehicles. The table also includes a comparison of the number of fatalities and seriously injured occupants depending on the vehicle type. As expected, the counts of killed and seriously injured occupants also increased over the five years included in the Table. Note that, up to 2016, no fatal or serious injuries in EV were identified in the DGT database.

In urban areas, after filtering only to frontal impacts in which all the occupants in the vehicle used the seatbelt and limiting the age of the ICE vehicle to be equal or less than three years old (to ensure that only newer vehicles were included in the comparison), the proportion of EV crashes involving killed occupants with respect to all EV crashes (n=1971) was 0.05% (95%CI: -0.03%, 0.13%) while this proportion was 0.04% (95%CI: 0.02%, 0.06%) for ICE vehicles (n=27591). These proportions were calculated also for crashes involving at least one seriously injured occupant (but not killed occupants) showing comparable results between the two vehicle types: 0.51% (95%CI: 0.24%, 0.77%) and 0.57 (95%CI: 0.50%, 0.65%). Thus, no statistically significant differences were identified between the two vehicle types in urban areas.

Outside urban areas and using the same filters (frontal impacts, all occupants belted and only newer models of ICE vehicles), the proportion of crashes of EV involving killed occupants with respect to all EV crashes (n=916) was 0.66% (95%CI: 0.22% - 1.09%) and 0.93% (95%CI: 0.84% - 1.01%) for ICE vehicles (n=35764). In the case of crashes involving seriously injured occupants, the proportions were 2.84% (95%CI: 1.94% - 3.74%) for EV and 3.14% (95%CI: 2.99% - 3.29%) for ICE vehicles. Similarly to what happened in urban environments, no statistical differences were found between the two vehicle types in the injury risk outside urban areas although the point estimates of the proportions are higher for ICE vehicles.

DISCUSSION

The data used in this pilot study are intended to be a census of the road collisions with injured victims occurring in Spanish roads, based on Police reports. As in many other countries, while the number of cases included in the database is very large (a few cases are never reported to the Police forces), the level of information available for each of the cases included in the database may not be enough to perform the assessment of particular vehicle technologies or estimations of the risk associated to travelling in a particular type of vehicle. In our efforts to obtain a sample of cases in which we could control for impact type, impact velocity, use of seat belt and other comparable crash circumstances that likely influence the injury outcome, we ended up with small sample sizes as several of the needed variables had missing information. This resulted in wide CI in the case of estimations concerning EV. It would have been interesting to separate in the study PHEV from BEV, but the sample size would have been even smaller to result in any meaningful comparison with ICE vehicles.

Despite these limitations, this pilot study suggests that belted EV occupants may have a lower risk of resulting killed or seriously injured in frontal impacts compared to belted ICE vehicles occupants outside urban areas, although this result was not statistically significant. This effect was not observed for the collisions occurring in urban areas. A contemporary study using Norwegian data, one of the countries with the highest rate of market penetration of electric vehicles in Europe, indicated that electric vehicle (EV) crashes did not show statistically significant differences in injury severity with respect to ICE vehicles (Liu et al., 2022). It should be noted that in the period between 2012 and 2018, there were only 342 EV crashes in Norway a number that is substantially lower than the one included in this study. Interestingly, the proportions of killed and seriously injured occupants in Norway were larger than the ones found in our study but we controlled by seat belt use and this variable was unaccounted for in the Norwegian one. Unfortunately, Liu et al. did not provide separate estimations of these proportions for urban and rural areas. The only two other studies reporting comparisons of the crash performance of EV and ICE vehicles included only a few cases of EV (n<55), precluding drawing any robust conclusion (Chen et al., 2015; Lopez-Valdes et al., 2018).

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TABLES AND FIGURES

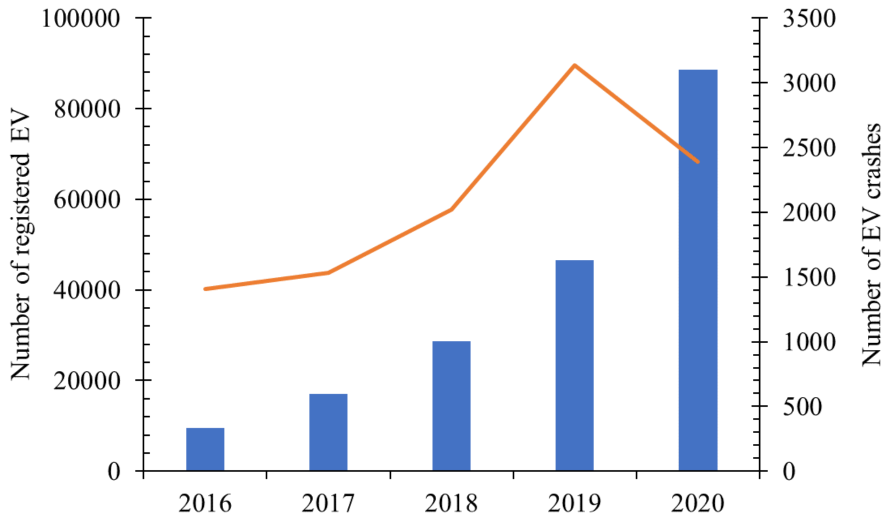

Figure 1 Increase in the number of EV (BEV+ PHEV) passenger cars (blue bars) and of EV crashes (orange line), 2016-2020.

Table 1 Frequency counts of collisions, fatalities and injured occupants per vehicle type in Spain (2016-2020)

	2016	2017	2018	2019	2020
EV collisions	1408	1535	2019	3134	2388
ICE vehicles collisions	161490	161379	160873	161419	109780
EV fatalities	3	8	4	4	5
ICE vehicles fatalities	1247	1284	1213	1178	953
EV seriously injured	16	21	25	37	37
ICE vehicles seriously injured	6100	5806	5440	5286	4168