Pedestrian safety on the road to net zero: cross-sectional study of collisions with electric and hybrid-electric cars in Great Britain

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ABSTRACT

Background Plans to phase out fossil fuel-powered internal combustion engine (ICE) vehicles and to replace these with electric and hybrid-electric (E-HE) vehicles represent a historic step to reduce air pollution and address the climate emergency. However, there are concerns that E-HE cars are more hazardous to pedestrians, due to being quieter. We investigated and compared injury risks to pedestrians from E-HE and ICE cars in urban and rural environments.

Methods We conducted a cross-sectional study of pedestrians injured by cars or taxis in Great Britain. We estimated casualty rates per 100 million miles of travel by E-HE and ICE vehicles. Numerators (pedestrians) were extracted from STATS19 datasets. Denominators (car travel) were estimated by multiplying average annual mileage (using National Travel Survey datasets) by numbers of vehicles. We used Poisson regression to investigate modifying effects of environments where collisions occurred.

Results During 2013–2017, casualty rates per 100 million miles were 5.16 (95% CI 4.92 to 5.42) for E-HE vehicles and 2.40 (95%CI 2.38 to 2.41) for ICE vehicles, indicating that collisions were twice as likely (RR 2.15; 95% CI 2.05 to 2.26) with E-HE vehicles. Poisson regression found no evidence that E-HE vehicles were more dangerous in rural environments (RR 0.91; 95% CI 0.74 to 1.11); but strong evidence that E-HE vehicles were three times more dangerous than ICE vehicles in urban environments (RR 2.97; 95% CI 2.41 to 3.7). Sensitivity analyses of missing data support main findings.

Conclusion E-HE cars pose greater risk to pedestrians than ICE cars in urban environments. This risk must be mitigated as governments phase out petrol and diesel cars.

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ Electric cars are quieter than cars with petrol or diesel engines and may pose a greater risk to pedestrians.
- ⇒ The US National Highway Transportation Safety Agency found that during 2000–2007 the odds of an electric or hybrid-electric car causing a pedestrian injury were 35% greater than a car with a petrol or diesel engine.
- ⇒ The UK Transport Research Laboratory found the pedestrian casualty rate per 10 000 registered electric or hybrid-electric vehicles during 2005–2007 in Great Britain was lower than the rate for petrol or diesel vehicles.

WHAT THIS STUDY ADDS

- ⇒ In Great Britain during 2013–2017, pedestrians were twice as likely to be hit by an electric or hybrid-electric car than by a petrol or diesel car; the risks were higher in urban areas.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ The greater risk to pedestrian safety posed by electric or hybrid-electric cars needs to be mitigated as governments proceed to phase out petrol and diesel cars.
- ⇒ Drivers of electric or hybrid-electric cars must be cautious of pedestrians who may not hear them approaching and may step into the road thinking it is safe to do so, particularly in towns and cities.

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INTRODUCTION

Background

Net zero

Many governments have set targets to reach net-zero emissions to help mitigate the harms of climate change. Short-term health benefits of reduced emissions are expected from better air quality with longer-term benefits from reduced global temperatures.[1]

Transition to electric and hybrid-electric (E-HE) cars

One such target is to phase out sales of new fossil fuel-powered internal combustion engine (ICE) vehicles and replace these with E-HE vehicles.[2 3]

Pedestrian safety

Road traffic injuries are the leading cause of death for children and young adults.[4] A quarter of all road traffic deaths are of pedestrians.[5] Concerns have been raised that E-HE cars may be more hazardous to pedestrians than ICE cars, due to being quieter.[6 7] It has been hypothesised that E-HE cars pose a greater risk of injury to pedestrians in urban areas where background ambient noise levels are higher.[8] However, there has been relatively little empirical research on possible impacts of E-HE cars on pedestrian road safety. A study commissioned for the US National Highway Transportation Safety Agency based on data from 16 States found that the odds of an E-HE vehicle causing a pedestrian injury were 35% greater than an ICE vehicle.[9] In contrast, a study commissioned by the UK Department for Transport found pedestrian casualty rates from collisions with E-HE vehicles during 2005–2007 were lower than for ICE vehicles.[10] Possible reasons for these conflicting results are that the two studies used different designs and estimated different measures of relative risk—the first used a case–control design and estimated an OR, whereas the second used a cross-sectional study and estimated a rate ratio. ORs will often differ from rate ratios.[11] Other reasons include differences between the USA and the UK in the amount and quality of walking infrastructure.[12]

Aim and objectives

We aimed to add to the evidence base on whether E-HE cars pose a greater injury risk to pedestrians than ICE cars by analysing road traffic injury data and travel survey data in Great Britain.

We sought to improve on the previous UK study by using distance travelled instead of number of registered vehicles as the measure of exposure in estimation of collision rates.

The objectives of this study were:

- To estimate pedestrian casualty rates for E-HE and ICE vehicles and to compare these by calculating a rate ratio;
- To assess whether or not the evidence supports the hypothesis that casualty rate ratios vary according to urban or rural environments.[8]

METHODS

Study design

This study was an analysis of differences in casualty rates of pedestrians per 100 million miles of E-HE car travel and rates per 100 million miles of ICE car travel.

Setting

This study was set in Great Britain between 2013 and 2017.

Participants

The study participants were all pedestrians reported to have been injured in a collision with a car or a taxi.

Exposure

The exposure was the type of propulsion of the colliding vehicle, E-HE or ICE. E-HE vehicles were treated as a single powertrain type, regardless of the mode of operation that a hybrid vehicle was in at the time of collision (hybrid vehicles typically start in electric mode and change from battery to combustion engine at higher speeds).[13]

Outcome

The outcome of interest was a pedestrian casualty.

Effect modification by road environment

We used the urban–rural classification[14] of the roads on which the collisions occurred to investigate whether casualty rate ratios comparing E-HE with ICE vehicles differed between rural and urban environments.

Data sources/measurement

Numerator data (numbers of pedestrians injured in collisions) were extracted from the Road Safety Data (STATS19) datasets.[15]

Denominator data (100 million miles of car travel per year) were estimated by multiplying average annual mileage by numbers of vehicle registrations.[16] Average annual mileage for E-HE and ICE vehicles was estimated separately for urban and rural environments using data obtained under special licence from the National Travel Survey (NTS) datasets.[17] We estimated average annual mileage for the years 2013–2017 because the NTS variable for the vehicle fuel type did not include 'hybrid' prior to 2013 and data from 2018 had not been uploaded to the UK data service due to problems with the archiving process (Andrew Kelly, Database Manager, NTS, Department for Transport, 23 March 2020, personal communication). Denominators were thus available for the years 2013–2017.

Data preparation

The datasets for collisions, casualties and vehicles from the STATS19 database were merged using a unique identification number for each collision.

Statistical methods

We calculated annual casualty rates for E-HE and ICE vehicles separately and we compared these by calculating a rate ratio. We used Poisson regression models to estimate rate ratios with 95% CIs and to investigate any modifying effects of the road environment in which the collisions occurred. For this analysis, our regression model included explanatory terms for the main effects of the road environment, plus terms for the interaction between type of propulsion and the road environment. The assumptions for Poisson regression were met in our study: we modelled count data (counts of pedestrians injured), traffic collisions were independent of each other, occurring in different places over time, and never occurring simultaneously. Data preparation, management and analyses were carried out using Microsoft Access 2019 and Stata V.16.[18]

Sensitivity analysis

We conducted an extreme case analysis where all missing propulsion codes were assumed to be ICE vehicles (there were over a 100 times more ICE vehicles than E-HE vehicles on the roads in Great Britain during our study period,[16] so missing propulsion is more likely to have been ICE).

Study size

The sample size for this study included all available recorded road traffic collisions in Great Britain during the study period. We estimated that for our study to have 80% power at the 5% significance level to show a difference in casualty rates of 2 per 100 miles versus 5.5 per 100 miles, we would require 481 million miles of vehicle travel in each group (E-HE and ICE); whereas to have 90% power at the 1% significance level to show this difference, 911 million miles of vehicle travel would be required in each group. Our study includes 32 000 million miles of E-HE vehicle travel and 3 000 000 million miles of ICE vehicle travel and therefore our study was sufficiently powered to detect differences in casualty rates of these magnitudes.

RESULTS

Participants

Between 2013 and 2017, there were 916 713 casualties from reported road traffic collisions in Great Britain. 120 197 casualties were pedestrians. Of these pedestrians, 96 285 had been hit by a car or taxi. Most pedestrians—71 666 (74%) were hit by an ICE car or taxi. 1652 (2%) casualties were hit by an E-HE car or taxi. For 22 829 (24%) casualties, the vehicle propulsion code was missing. Most collisions occurred in urban environments and a greater proportion of the collisions with E-HE vehicles occurred in an urban environment (94%) than did collisions with ICE vehicles (88%) (figure 1).

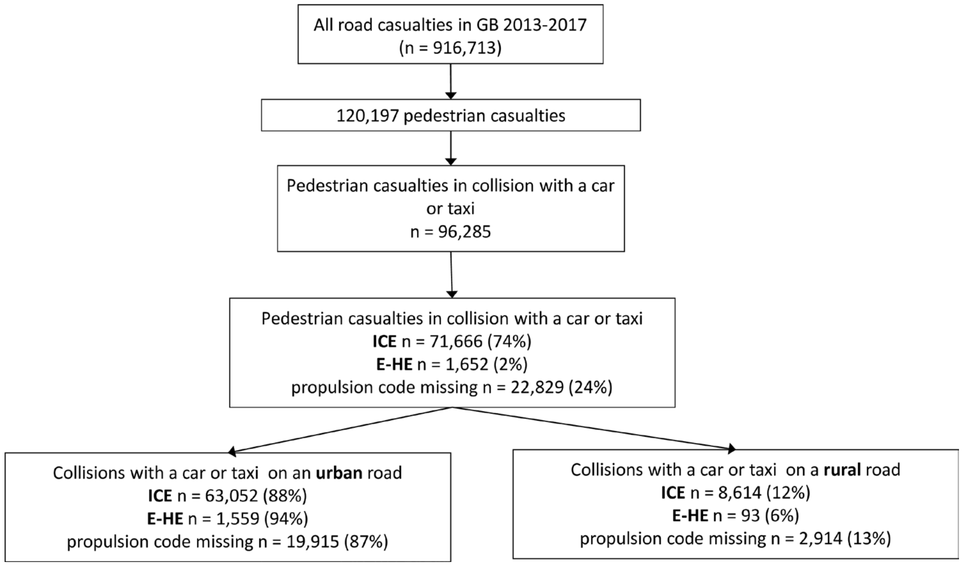

Figure 1 Flow chart of pedestrian casualties in collisions with E-HE or ICE cars or taxis from reported road traffic collisions in Great Britain 2013–2017. E-HE, electric and hybrid-electric; ICE, internal combustion engine.

Main results

During the period 2013 to 2017, the average annual casualty rates of pedestrians per 100 million miles were 5.16 (95% CI 4.92 to 5.42) for E-HE vehicles and 2.40 (95% CI 2.38 to 2.41) for ICE vehicles, which indicates that collisions with pedestrians were on average twice as likely (RR 2.15 (95% CI 2.05 to 2.26), p<0.001) with E-HE vehicles as with ICE vehicles (table 1).

Sensitivity analysis

In our extreme case analysis, the 22 829 pedestrian casualties where vehicle propulsion was missing were all assumed to have been struck by ICE vehicles. In this case, average casualty rates of pedestrians per 100 million miles were 3.16 (95% CI 3.14 to 3.18) for ICE vehicles, which would indicate that collisions with pedestrians were on average 63% more likely (RR 1.63 (95% CI 1.56 to 1.71), p<0.001) with E-HE vehicles than with ICE vehicles (table 2).

Relative risks according to road environment

Casualty rates were higher in urban than rural environments (tables 3 and 4).

Urban environments

Collisions with pedestrians in urban environments were on average over two and a half times as likely (RR 2.69 (95% CI 2.56 to 2.83, p<0.001) with E-HE vehicles as with ICE vehicles (table 3).

Sensitivity analysis

The extreme case sensitivity analysis showed collisions with pedestrians in urban environments were more likely with E-HE vehicles (RR 2.05; 95% CI 1.95 to 2.15).

Rural environments

Collisions with pedestrians in rural environments were equally likely (RR 0.91; 95% CI 0.74 to 1.11) with E-HE vehicles as with ICE vehicles (table 4).

Sensitivity analysis

The extreme case sensitivity analysis found evidence that collisions with pedestrians in rural environments were less likely with E-HE vehicles (RR 0.68; 95% CI 0.55 to 0.83).

Results of Poisson regression analysis

Our Poisson regression model results (table 5) showed that pedestrian injury rates were on average 9.28 (95% CI 9.07 to 9.49) times greater in urban than in rural environments. There was no evidence that E-HE vehicles were more dangerous than ICE vehicles in rural environments (RR 0.91; 95% CI 0.74 to 1.11), consistent with our finding in table 4. There was strong evidence that E-HE vehicles were on average three times more dangerous than ICE vehicles in urban environments (RR 2.97; 95% CI 2.41 to 3.67).

DISCUSSION

Statement of principal findings

This study found that in Great Britain between 2013 and 2017, casualty rates of pedestrians due to collisions with E-HE cars and taxis were higher than those due to collisions with ICE cars and taxis. Our best estimate is that such collisions are on average twice as likely, and in urban areas E-HE vehicles are on average three times more dangerous than ICE vehicles, consistent with the theory that E-HE vehicles are less audible to pedestrians in urban areas where background ambient noise levels are higher.

Table 1 Pedestrian casualties due to collisions with cars or taxis from reported road traffic collisions in Great Britain 2013–2017—by vehicle propulsion type

Vehicle propulsion	Pedestrian casualties	Annual mileage (100 million miles)	Average casualty rate per 100 million miles	Casualty rate ratio E-HE versus ICE
E-HE	1652	320	5.16 (95% CI 4.92 to 5.42)	2.15 (95% CI 2.05 to 2.26)
ICE	71 666	29 896	2.40 (95% CI 2.38 to 2.41)	

E-HE, electric and hybrid-electric; ICE, internal combustion engine.

Table 2 Extreme case sensitivity analysis—pedestrian casualties due to collisions with cars or taxis from reported road traffic collisions in Great Britain 2013–2017 by vehicle propulsion type where 22 829 missing vehicle propulsion codes are assumed to be ICE vehicles

Vehicle propulsion type	Pedestrian casualties	Annual mileage (100 million miles)	Average casualty rate per 100 million miles	Casualty rate ratio E-HE versus ICE
E-HE	1652	320	5.16 (95% CI 4.92 to 5.42)	1.63 (95% CI 1.56 to 1.71)
ICE	94 495	29 896	3.16 (95% CI 3.14 to 3.18)	

E-HE, electric and hybrid-electric; ICE, internal combustion engine.

Strengths and weaknesses of the study

There are several limitations to this study which are discussed below.

The data used were not very recent. However, ours is the most current analysis of E-HE vehicle collisions using the STATS19 dataset.

Before we can infer that E-HE vehicles pose a greater risk to pedestrians than ICE vehicles, we must consider whether our study is free from confounding and selection bias. Confounding occurs when the exposure and outcome share a common cause.[19] Confounders in this study would be factors that may both cause a traffic collision and also cause the exposure (use of an E-HE car). Younger, less experienced drivers (ie, ages 16–24) are more likely to be involved in a road traffic collision[20] and are also more likely to own an electric car.[21] Some of the observed increased risk of electric cars may therefore be due to younger drivers preferring electric cars. This would cause positive confounding, meaning that the true relative risk of electric cars is less than we have estimated in our study. Regarding selection bias, it is known that the STATS19 dataset does not include every road traffic casualty in Great Britain, as some non-fatal casualties are not reported to the police.[22] If casualties from collisions are reported to the police differentially according to the type of vehicle propulsion, this may have biased our results; however, there is no reason to suspect that a pedestrian struck by a petrol or diesel car is any more or less likely to report the collision to the police than one struck by an electric car.

We must also address two additional concerns as ours is a cross-sectional study: The accuracy of exposure assignment (including the potential for recall bias) and the adequacy of prevalence as a proxy for incidence.[23] First, the accuracy of exposure assignment and the potential for recall bias are not issues for this study, as the exposure (type of propulsion of the colliding vehicle, E-HE or ICE), is assigned independently of the casualties by the UK Department for Transport who link the vehicle registration number (VRN) of each colliding vehicle to vehicle data held by the UK Driver Vehicle and Licensing Agency (DVLA).[10] Second, we have not used prevalence as a proxy for incidence but have estimated incidence using total distance travelled by cars as the measure of exposure.

We may therefore reasonably infer from our study results that E-HE vehicles pose a greater risk to pedestrians than ICE vehicles in urban environments, and that part of the risk may be due to younger people's preference for E-HE cars.

A major limitation of the STATS19 road safety dataset used in this study was that it did not contain a vehicle propulsion code for all vehicles in collisions with pedestrians. We excluded these vehicles from our primary analysis (a complete case analysis) and we also conducted an extreme case sensitivity analysis. We will now argue why imputation of missing vehicle propulsion codes would not have added value to this study. Vehicle propulsion data are obtained for the STATS19 dataset by the UK Department for Transport who link the VRN of each colliding vehicle recorded in STATS19 to vehicles data held by the UK DVLA. The STATS19 data on reported collisions and casualties are collected by a Police Officer when an injury road accident is reported to them; Most police officers write details of the casualties and the vehicles involved in their notebooks for transcription onto the STATS19 form later at the Police station.[24] The VRN is one of 18 items recorded on each vehicle involved in a collision. Items may occasionally be missed due to human error during this process. Where a VRN is missing, vehicle propulsion will be missing in the STATS19 dataset. The chance that any vehicle-related item is missing will be independent of any characteristics of the casualties involved and so the vehicle propulsion codes are missing completely at random (MCAR). As the missing propulsion data are very likely MCAR, the set of pedestrians with no missing data is a random sample from the source population and hence our complete case analysis for handling the missing data gives unbiased results. The extreme case sensitivity analysis we performed shows a possible result that could occur, and it demonstrates our conclusions in urban environments are robust to the missing data. Lastly, to impute the missing data would require additional variables which are related to the likelihood of a VRN being missing. Such variables were not available and therefore we do not believe a useful multiple imputation analysis could have been performed.

Strengths and weaknesses in relation to other studies

Our study uses hundreds of millions of miles of car travel as the denominators in our estimates of annual pedestrian casualty rates which is a more accurate measure of exposure to road hazards than the number of registered vehicles, which was used as the denominator in a previous study in the UK.[10] Our results differ to this previous study which found that pedestrian casualty rates from collisions with E-HE vehicles during 2005–2007 were lower than those from ICE vehicles. Our study has updated

Table 3 Pedestrian casualties due to collisions with cars or taxis from reported road traffic collisions in Great Britain 2013–2017—by vehicle propulsion type in *urban* road environments

Vehicle propulsion	Pedestrian casualties	Annual mileage (100 million miles)	Average casualty rate per 100 million miles	Casualty rate ratio E-HE versus ICE
E-HE	1559	121	12.9 (95% CI 12.3 to 13.5)	2.69 (95% CI 2.56 to 2.83)
ICE	63 052	13 182	4.78 (95% CI 4.75 to 4.82)	

E-HE, electric and hybrid-electric; ICE, internal combustion engine.

Table 4 Pedestrian casualties due to collisions with cars or taxis from reported road traffic collisions in Great Britain 2013–2017—by vehicle propulsion type in *rural* road environments

Vehicle propulsion	Pedestrian casualties	Annual mileage (100 million miles)	Average casualty rate per 100 million miles	Casualty rate ratio E-HE versus ICE
E-HE	93	199	0.47 (95% CI 0.38 to 0.57)	0.91 (95% CI 0.74 to 1.11)
ICE	8614	16 714	0.52 (95% CI 0.50 to 0.53)	

E-HE, electric and hybrid-electric; ICE, internal combustion engine.

this previous analysis and shows that casualty rates due to E-HE vehicle collisions exceed those due to ICE vehicle collisions. Similarly, our study uses a more robust measure of risk (casualty rates per miles of car travel) than that used in a US study.[9] Our study results are consistent with this US study that found that the odds of an E-HE vehicle causing a pedestrian injury were 35% greater than an ICE vehicle. Brand *et al*[8] hypothesised, without any supporting data, that “hybrid and electric low-noise cars cause an increase in traffic collisions involving vulnerable road users in urban areas” and recommended that “further investigations have to be done with the increase of low-noise cars to prove our hypothesis right.”[8] We believe that our study is the first to provide empirical evidence in support of this hypothesis.

Meaning of the study: possible explanations and implications for clinicians and policymakers

More pedestrians are injured in Great Britain by petrol and diesel cars than by electric cars, but compared with petrol and diesel cars, electric cars pose a greater risk to pedestrians and the risk is greater in urban environments. One plausible explanation for our results is that background ambient noise levels differ between urban and rural areas, causing electric vehicles to be less audible to pedestrians in urban areas. Such differences may impact on safety because pedestrians usually hear traffic approaching and take care to avoid any collision, which is more difficult if they do not hear electric vehicles. This is consistent with audio-testing evidence in a small study of vision-impaired participants.[10] From a Public Health perspective, our results should not discourage active forms of transport beneficial to health, such as walking and cycling, rather they can be used to ensure that any potential increased traffic injury risks are understood and safeguarded against. A better transport policy response to the climate emergency might be the provision of safe, affordable, accessible and integrated public transport systems for all.[25]

Unanswered questions and future research

It will be of interest to investigate the extent to which younger drivers are involved in collisions of E-HE cars with pedestrians.

If the braking distance of electric cars is longer,[26] and electric cars are heavier than their petrol and diesel counterparts,[27] these factors may increase the risks and the severity of injuries sustained by pedestrians and require investigation.

As car manufacturers continue to develop and equip new electric cars with Collision Avoidance Systems and Autonomous Emergency Braking to ensure automatic braking in cases where pedestrians or cyclists move into the path of an oncoming car, future research can repeat the analyses presented in this study to evaluate whether the risks of E-HE cars to pedestrians in urban areas have been sufficiently mitigated.

Table 5 Results of Poisson regression analysis of annual casualty rates of pedestrians per 100 million miles by road environment and the interaction between vehicle propulsion type and environment

Explanatory variables	Rate ratio	P value
Road environment		
Rural	1 (referent)	
Urban	9.28 (95% CI 9.07 to 9.49)	<0.001
Interactions between vehicle propulsion and road environment		
E-HE versus ICE in rural areas	0.91 (95% CI 0.74 to 1.11)	0.348
E-HE versus ICE in urban areas	2.97 (95% CI 2.41 to 3.67)	<0.001

E-HE, electric and hybrid-electric; ICE, internal combustion engine.

CONCLUSIONS

E-HE vehicles pose a greater risk to pedestrians than petrol and diesel powered vehicles in urban environments. This risk needs to be mitigated as governments proceed to phase out petrol and diesel cars.

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Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by the LSHTM MSc Research Ethics Committee (reference #16400). The study uses the anonymised records of people injured in road traffic collisions, data which are routinely collected by UK police forces. The participants are unknown to the investigators and could not be contacted.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open-access repository. Numerator data (numbers of pedestrians injured in collisions) are publicly available from the Road Safety Data (STATS19) datasets (https://www.data.gov.uk/dataset/cb7ae6f0-4be6-4935-9277-47e5ce24a11f/road-safety-data). Denominator data (100 million miles of car travel per year) may be estimated by multiplying average annual mileage by numbers of vehicle registrations (publicly available from Department for Transport, https://www.gov.uk/government/statistical-data-sets/veh02-licensed-cars). Average annual mileage for E-HE and ICE vehicles may be estimated separately for urban and rural environments using data that may obtained under special licence from the National Travel Survey datasets (http://doi.org/10.5255/UKDA-Series-2000037).

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