Driver obesity and the risk of fatal injury during traffic collisions

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ABSTRACT
Background Few studies have looked at how obesity affects injury outcomes among vehicle occupants involved in traffic collisions.

Objective To estimate the association of obesity with death risk among drivers of passenger vehicles aged ≥16 and to examine effect modification by driver sex, driver seat belt use, vehicle type and collision type.

Methods We conducted a matched-pair cohort study using data from the Fatality Analysis Reporting System. WHO body mass index (BMI) categories were calculated. Data were analysed using conditional Poisson regression.

Results Estimated risk ratios (RRs) were slightly raised for overweight drivers (RR=1.19, 95% CI 0.86 to 1.63). RR increased with higher BMI categories and were 1.21 (0.98 to 1.49) for BMI 30–34.9, 1.51 (1.10 to 2.08) for BMI 35–39.9 and 1.80 (1.15 to 2.84) for BMI ≥40. Estimated BMI effects varied by gender. We found no meaningful variation across levels of vehicle type, collision type or seat belt use.

Conclusions Findings from this study suggest that obese vehicle drivers are more likely to die from traffic collision-related injuries than non-obese occupants involved in the same collision. Education is needed to improve seat belt use among obese people, as is research to understand the potential role of comorbidities in injury outcomes.

INTRODUCTION
Each year in the USA an estimated 300 000 people die from obesity-related causes.1 Obesity is also known to increase morbidity and decrease quality of life.2–3 Although there is a large body of research on the health consequences of obesity, few studies have looked at how obesity affects non-fatal injury outcomes among vehicle occupants involved in traffic collisions and even fewer have looked at the association between obesity and the occurrence of fatal injury.

Mock et al4 used data from a national collision data system to estimate the effect of obesity on death and on Injury Severity Score. They reported that both weight and body mass index (BMI) significantly increased the risk of death and the risk of severe injury (Injury Severity Score ≥9), after adjusting for potential confounders. BMI (weight (kg)/height (m)²) is a body composition measure commonly used in medical and public health practice and research. More recently, Zhu et al5 examined data from the same source and reported that the risk of death among men increased greatly for both low and high BMI values, relative to normal BMI, but found no differences among women. Because the data source used in these studies included about 100 fatal collisions a year, both analyses were statistically limited.

The goal of this study was to provide knowledge on how the obesity of occupants influences the risk of fatal injury and interacts with vehicle and occupant risk factors during severe traffic collisions. We used a significantly larger sample than has been used in previous studies. The specific objectives were to (1) estimate the association of obesity with death risk among drivers of passenger vehicles aged ≥16 and (2) determine whether obesity effects are influenced by vehicle and collision characteristics, such as driver sex, driver seat belt use, vehicle type and collision type.

METHODS AND PROCEDURES
Study design
A matched-pair cohort study was conducted using data from the Fatality Analysis Reporting System (FARS). Pairs of passenger vehicle drivers whose vehicles collided were identified in FARS and death risk ratios (RRs) for obesity measures were estimated, adjusting for a variety of potentially confounding characteristics. Driver pairs were included only if the two vehicles were of similar type and size. This was done to reduce the possibility of confounding due to an association between driver weight or height and vehicle size. Fatality RRs were estimated with a conditional Poisson regression model.

The matched-cohort design is appropriate because collision data from FARS and similar data systems possess a characteristic known as ‘natural matching’.6 This quality is present because, when two or more drivers are involved in a traffic collision, they share values for most crash variables. For example, two drivers involved in a collision will have the same values for factors such as time of day, ambulance response time and numerous roadway and environmental characteristics. This matching has two favourable consequences. First, it allows fatality RRs to be estimated despite the lack of information on vehicles involved in the collision in which no occupant died,7 as is the case when using data from a fatal injury surveillance system such as FARS. Second, conditioning on the matching controls for potential confounding by a variety of factors that are the same for people within the matched pairs or sets.8 These include measured factors such as time of day and road type as well as unmeasured factors such as crash energy and quality of emergency medical services.

Matched-cohort methods have been used for a variety of research topics, including seat belts,9 child restraints,10,11 occupant seating position,12 air bags,13,14 motorcycle helmets,15 and pick-up truck cargo area travel.16 Matched-set cohort
methods can be applied to sets of occupants’ data from within vehicles12 14–16 or within collisions.13 17

Data
Data for years 1996–2008 were obtained from FARS, a census of fatal US traffic collisions operated by the National Highway Traffic Safety Administration. The objective of FARS is to identify and collect information on all traffic collisions in the USA that result in death within 30 days. Collisions were identified in which two passenger vehicles (cars, pick-up trucks, SUVs and minivans) in the years 1996–2008 were involved and during which the most harmful event was an impact between the vehicles. Of these 57 491 collisions, 41 296 were retained because both drivers were known to be aged ≥16 and one or both drivers died. Thirteen collisions were then excluded because no person or more than one person was coded as a driver. The resulting dataset contained information on 82 566 drivers involved in 41 283 collisions. The VINDICATOR database18 was used to link FARS vehicle identification numbers to information on vehicle characteristics, including body style and vehicle size. Vehicle body and size were used to create seven type–size categories (small, medium and large passenger cars; small, medium and large light trucks; and minivans). Information on 3403 pairs of drivers who were operating vehicles in the same type–size category were selected for the analysis.

Variables
The injury severity variable was recoded to form a fatality outcome variable. Driver weight and driver height, originating from state driver licence databases, were available for about 75% of drivers. BMI was calculated and categorised using the WHO BMI classification—underweight (<18.5), normal (18.5–24.9), overweight (25–29.9), obese class I (30–34.9), obese class II (35–39.9) and obesity class III (≥40). The restraint use variables in FARS capture police-determined seat belt use and air bag deployment. We created a binary indicator for properly belted drivers, compared with unbelted or improperly belted (lap only, shoulder only, or other improper use) drivers. Driver age was categorised as 15–24, 25–34, 35–44, 45–54 or 55–64. Time of collision was categorised into 3 h intervals. Variables were also obtained for driver sex, driver alcohol use and collision type.

Statistical modelling
Adjusted RRs were estimated with conditional Poisson regression and standard errors were obtained with a bootstrap.19 RR and CI were estimated for each level of WHO BMI category, using the normal BMI category as referent. Each model also included age category, sex, alcohol use, seat belt use and air bag deployment. Potential effect modification was examined by entering product terms into the models to allow the obesity RR estimates to vary across levels of sex, seat belt use, head-on collision status and vehicle type.

RESULTS
Six thousand eight hundred and six drivers involved in 3403 collisions were identified for analysis. Of the drivers with complete information on height and weight, 46% had normal BMI, 33% had overweight BMI and 18% were in one of the three WHO obese BMI categories (table 1).

Two-thirds of drivers were men (67%) and 31% of drivers were aged 16–24 years. Thirty-three per cent of drivers were unbelted and 53% experienced an air bag deployment.

RR increased with higher BMI categories (table 2). Adjusted RR (95% CI) for WHO obese levels I, II and III were 1.21 (0.98 to 1.49), 1.51 (1.10 to 2.08) and 1.80 (1.15 to 2.84), respectively, compared with normal weight drivers. Estimated BMI effects varied significantly by gender (Wald p=0.02) (figure 1). An increased risk of death was seen for underweight (BMI<18.5) men (RR=1.78, 95% CI 1.01 to 3.14) but not for underweight women (RR=0.99, 95% CI 0.66 to 1.46). RR for each of BMI levels I, II and III were greater for women than for men. We found no meaningful effect modification by vehicle type (p 0.16), head-on collision status (p 0.59) or seat belt use (p 0.94).

DISCUSSION
In this study, we found an association between obesity and the risk of death among drivers involved in severe motor vehicle collisions. We estimated moderate increases in mortality risk among underweight and obese drivers, compared with normal weight drivers. We found larger increases in the risk of death for higher levels of obesity. Drivers in WHO obese classes II and III were 48% and 78% more likely, respectively, to have a fatal injury than normal BMI drivers. Our estimates were adjusted for a variety of potential confounders—age category, sex, alcohol use, seat belt use and air bag deployment.

We examined potential effect measure modification by sex, vehicle type, collision type and seat belt use. We found meaningful effect modification by sex only. An increase in risk of death for underweight drivers, compared with normal weight drivers was seen in male drivers only (RR=1.78, 95% CI 1.01 to 3.14).

Table 1 Driver characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass index</td>
<td></td>
</tr>
<tr>
<td>Underweight (&lt;18.5)</td>
<td>177 (3)</td>
</tr>
<tr>
<td>Normal (18.5–24.9)</td>
<td>2404 (35)</td>
</tr>
<tr>
<td>Overweight (25–29.9)</td>
<td>1720 (25)</td>
</tr>
<tr>
<td>Obese I (30–35)</td>
<td>628 (9)</td>
</tr>
<tr>
<td>Obese II (35–39.9)</td>
<td>202 (3)</td>
</tr>
<tr>
<td>Obese III (≥40)</td>
<td>94 (1)</td>
</tr>
<tr>
<td>Unknown</td>
<td>1581 (23)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>2247 (33)</td>
</tr>
<tr>
<td>Male</td>
<td>4559 (67)</td>
</tr>
<tr>
<td>Age category</td>
<td></td>
</tr>
<tr>
<td>16–24</td>
<td>2134 (31)</td>
</tr>
<tr>
<td>25–34</td>
<td>1474 (22)</td>
</tr>
<tr>
<td>35–44</td>
<td>1274 (19)</td>
</tr>
<tr>
<td>45–54</td>
<td>1117 (16)</td>
</tr>
<tr>
<td>55–64</td>
<td>807 (12)</td>
</tr>
<tr>
<td>Seat belt use</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>2280 (33)</td>
</tr>
<tr>
<td>Yes</td>
<td>3940 (58)</td>
</tr>
<tr>
<td>Unknown</td>
<td>586 (9)</td>
</tr>
<tr>
<td>Air bag deployment</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>2449 (36)</td>
</tr>
<tr>
<td>Yes</td>
<td>3613 (53)</td>
</tr>
<tr>
<td>Unknown</td>
<td>744 (11)</td>
</tr>
<tr>
<td>Fatal injury</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>3033 (45)</td>
</tr>
<tr>
<td>No</td>
<td>3773 (55)</td>
</tr>
<tr>
<td>Total</td>
<td>6806 (100)</td>
</tr>
</tbody>
</table>
Conversely, the excess death risk associated with being overweight was higher among women than men. The estimated RRs for BMI obese classes I, II and III, respectively, were 1.36, 2.20 and 1.92 for women and 1.11, 1.25 and 1.75 for men.

To examine the sensitivity of results to our seat belt coding we recoded lap only, shoulder only and improper belt use as ‘belted’ and refitted the models. All model coefficients were nearly identical.

Most other studies have examined the influence of obesity on injury to a particular body region using small clinical populations. For example, Arbabi et al. analysed data from 189 people identified by a University of Michigan crash surveillance programme. Their findings were inconclusive—obesity was associated with a decrease in overall injury severity and an increase in mortality—possibly resulting from the limited data sample. In another study that examined the risk of diaphragm injury across levels of BMI, Reiff et al. reported that BMI increased injury risk only in near-side impact collisions but not in frontal collisions. Also, Schiff et al. examined risk factors for pelvic fracture among vehicle occupants involved in a collision and identified advanced age, female sex and below-normal BMI as predictors of pelvic fracture risk.

Finally, a small body of research has looked at whether obesity increases the risk of death among people who have a non-motor vehicle traumatic injury. Mock et al. conducted a retrospective cohort study using data from the Crashworthiness Data System, a national probability sample of passenger vehicle collisions. They reported a monotonic increase in risk of death with driver obesity. After adjustment for confounders, they reported a fatality OR of 1.60 for drivers in BMI category 35–39.9 and of 1.62 for drivers with BMI of ≥40 (each compared with normal BMI). These results closely match our estimated RR of 1.51 and 1.80 for the same categories. These two analyses were conducted using different national data sources and different methods.

Brown et al. reported that obese intensive care unit patients presented with different injury patterns than did non-obese patients (eg, fewer head injuries and more chest injuries) and, after accounting for differences in overall injury severity, had more complications, required longer hospital stays and were more likely to die from their injuries. They reported a fatality OR of 1.6 comparing obese (BMI >30) with non-obese patients. This result is also consistent with our RR estimates of 1.21, 1.51 and 1.80 for WHO obese classes I, II and III, respectively.

More recently, Viano et al. analysed data from the Crashworthiness Data System and reported that obese drivers were 97% more likely to have a fatal injury during collisions

<table>
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<tr>
<th>Table 2</th>
<th>Body mass index, fatality risk ratios (RR) and 95% CI, by sex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass index category</td>
<td>Female drivers</td>
</tr>
<tr>
<td>Underweight (&lt;18.5)</td>
<td>0.99</td>
</tr>
<tr>
<td>Normal (18.5–24.9)</td>
<td>Ref.</td>
</tr>
<tr>
<td>Overweight (25–29.9)</td>
<td>1.26</td>
</tr>
<tr>
<td>Obese I (30–34.9)</td>
<td>1.36</td>
</tr>
<tr>
<td>Obese II (35–39.9)</td>
<td>2.20</td>
</tr>
<tr>
<td>Obese III (≥40)</td>
<td>1.92</td>
</tr>
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*Wald p for effect modification by sex, 0.02.
than normal weight drivers.\textsuperscript{24} The analysis was limited by a lack of inclusion of any potential confounders and by the use of simplistic statistical methods.

Our analysis is strengthened by the use of a matched-cohort design which allowed for the control of unmeasured potential confounders. The multivariate regression model also permitted the control of additional potential confounders. In addition, the use of the FARS data system allowed for a data sample with significantly more statistical power than would have been possible with other national datasets. Lastly, we included only collision-involved drivers of passenger vehicles of similar size to control for confounding owing to an association between driver obesity and vehicle size.

Our study has several limitations. BMI was calculated using the height and weight information in FARS, which originates from motor vehicle state departments. It is likely that weight is infrequently updated by these agencies and may not accurately reflect drivers’ current weight. Height and weight are available in FARS for drivers only. This made matching occupants within vehicles impossible and reduced the sample size. In addition, height and weight were not available for 23\% of our sample of drivers.

The ability of passenger vehicles to protect overweight or obese occupants may have increasingly important public health implications, given the continuing obesity epidemic in the USA. The prevalence of moderate and severe obesity in the USA has increased for more than 20 years and may only now be stabilising.\textsuperscript{25, 26} Currently, more than 33\% of adult men and 35\% of adult women are obese (BMI\geq30).\textsuperscript{27} It may be the case that passenger vehicles are well designed to protect normal weight vehicle occupants but are deficient in protecting overweight or obese occupants.

Potential mechanisms for higher severity injuries among obese vehicle occupants have been explored by Kent et al.\textsuperscript{28} They conducted crash tests using obese and normal cadavers. They found that during frontal collisions normal cadavers had a moderate degree of forward movement before the seat belt engaged the pelvis to prevent further forward movement. Obese cadavers had significantly more forward movement away from the vehicle seat before the seat belt engaged the pelvis owing to additional soft tissue that prevents the belt from fitting close to the pelvis when the cadavers were in the driving position. The additional forward motion by cadavers was seen for the abdomen and lower extremities. They found that obese cadavers actually had less upper body forward movement than normal weight cadavers.

Increased comorbidities among obese vehicle occupants are a probable contributor to their poor injury outcomes. The most commonly used state and national traffic collision databases do not have comorbidity information, but efforts to link medical information to collision databases might prove useful in studying the role of comorbidities in injury outcomes.

Clinical interventions could inform obese patients of the additional traffic injury risks and potential benefits of losing weight. Efforts to educate obese drivers about the importance of the proper use of the lap belt may lead to reductions in severe and fatal injuries, particularly among women. Our finding of no interaction between seat belt use and obesity suggests that seat belt effectiveness does not vary meaningfully across obesity levels and that lower seat belt effectiveness among obese drivers does not explain their poorer outcomes.

Contributors TMR designed the study, analysed and interpreted the data and drafted the manuscript. MZ interpreted the data and revised the paper.

Competing interests None.

Provenance and peer review Not commissioned; externally peer reviewed.

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