Obesity and Non-fatal Motor Vehicle Crash Injuries: Sex Difference Effects

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Abstract

Background—Obesity and motor vehicle crash (MVC) injuries are two parallel epidemics in the United States. An important unanswered question is if there are sex differences in the associations between the presence of obesity and non-fatal MVC injuries.

Objectives—To further understand the association between obesity and non-fatal motor vehicle crash injuries, particularly the sex differences in these relations.

Methods—We examined this question by analyzing data from the 2003 to 2007 National Automotive Sampling System Crashworthiness Data System (NASS CDS). A total of 10, 962 drivers who were aged 18 years or older and who survived frontal collision crashes were eligible for study.

Results—Male drivers experienced a lower rate of overall non-fatal MVC injuries than did female drivers (38.1% vs. 52.2%) but a higher rate of severe injuries (0.7% vs. 0.2%). After adjusting for change in velocity (V) during the crashes, obese male drivers showed a much higher risk [logistic coefficients of BMI for moderate, serious, and severe injury are 0.0766, 0.1470, and 0.1792, respectively; all $p<0.05$] of non-fatal injuries than did non-obese male drivers and these risks increased with injury severity. Non-fatal injury risks were not found to be increased in obese female drivers. The association between obesity and risk of non-fatal injury was much stronger for male drivers than for female drivers.

Conclusion—The higher risk of non-fatal MVC injuries in obese male drivers might result from their different body shape and fat distribution compared with obese female drivers. Our findings should be considered for obesity reduction, traffic safety evaluation and vehicle design for obese male drivers and provide testable hypotheses for future studies.

INTRODUCTION

Two public health issues have emerged over the past several decades that together represent major concerns and challenges in the United States and much of the world: the increasing prevalence of obesity and the large number of injuries and fatalities resulting from motor vehicle crashes (MVCs). Obesity is a risk factor for 7 of the 10 leading causes of death that decrease overall lifespan in the United States.[1, 2] The prevalence of obesity has doubled in the United States over the past 15 years, and roughly one third of the population is obese and nearly two thirds is overweight or obese.[3–5] Another public health issue, MVCs, was the leading cause of unintentional injury for people aged 15 to 44 years and accounted for more than 43, 000 United States deaths and 2.6 million injuries in 2005.[6, 7]

Several studies have shown that obesity is associated with an increased risk of fatal injury from MVCs; however, the evidence on the relationship between MVCs and non-fatal injury remains limited.[8–14] Arbabi et al. identified an increased risk of fatal MVCs associated with obesity but did not find a significant increase in the risk of non-fatal injury as defined by Injury Severity Score (ISS).[8] The authors speculated that the increased risk of fatal MVCs was attributable to the difficulty of post-injury care of obese victims or to medical comorbidities associated with obesity. Arbabi et al. suggested that the increased risk of fatal MVCs was unlikely secondary to an increased injury severity for obese vehicle occupants.[8]

Similar conclusions were drawn by Ryb et al. for obese subjects in comparison with normal weight subjects.[11] Mock et al., however, found that both fatality and injury risk were associated with occupants' body weight and proposed a view contrary to that of Arbabi et al. suggesting that the increased fatality rate associated with obesity might be due to injury severity rather than to the difficulty of post-injury care.[8, 12] Thus, uncertainty remains about the mechanisms of the increased risk of fatality and the associations with injury severity among obese motor vehicle occupants.

A previous report from our group demonstrated that the patterns of association between obesity and risk of fatality from MVCs differed for male and female drivers.[15] Our recent study describing the association between obesity and regional body injury following MVCs confirmed the previous sex difference in fatal findings based on both real-world and computer simulation data and indicated that obese male drivers experienced a much higher risk of injury to upper body regions.[16] The reasons for this sex difference are not well understood. Several factors that differ between obese males and females, such as body shape and fat distribution as mentioned by Arbabi et al. and Wang et al., are claimed to be associated with the outcomes of MVCs and might account for this sex difference.[8, 17] To date, this sex difference in MVC risk has been addressed only for fatal injuries. Determining whether a difference also exists for non-fatal injuries is important to provide evidence for the mechanisms of the increased risk of fatality associated with obesity. Moreover, the different patterns of obesity and fat distribution between men and women provide a feasible approach for examining the impact of sex differences on non-fatal MVC injuries.[18]

Therefore, to further understand the association between obesity and non-fatal MVC injuries, particularly the sex differences in these relations, we conducted the present study by use of a nationally representative database. We hypothesized that the risk of non-fatal MVC injuries would increase with the presence of obesity and that this association would be stronger in men than in women as we found for fatal and body regional injuries.

METHODS

Database and Sample

We used data from the National Automotive Sampling System (NASS) Crashworthiness Data System (CDS) from 2003 to 2007 in the United States. The NASS CDS is a nationwide data collection program based on cases selected from a national probability sample that are involved in police-reported MVCs and recorded on police accident reports. The details of the NASS CDS have been described elsewhere.[19, 20]

Surviving drivers of passenger cars or light trucks who were 18 years old or older and were involved in frontal-collision MVCs were eligible for this study. Various exclusion criteria were applied before analysis. We excluded pregnant female drivers (n=109) and individuals with missing data on sex (n=7), or height and weight (n=2170). To avoid potential errors during measurement or input of data collection, the 1st and 99th percentiles of the body mass index (BMI) distribution were considered as outliers and were excluded from the analysis, i.e., BMI less than 17.36 (n=109) or greater than 45.91 (n=113). In the end, a total of 10,962 subjects were analyzed.

Measures

The severity of non-fatal injury defined by the ISS was used as the outcome. The ISS score was calculated by adding the squares of the highest (Abbreviated Injury Score) AIS entries for each of the three most severely injured body regions.[21] Four different binary classifications of MVC injury severity were defined on the basis of four ISS cutoffs: no injury vs overall injury (ISS =0 vs ISS >0), moderate or less injury vs moderate-plus injury (ISS ≤ 8 vs ISS >8), serious or less injury vs serious-plus injury (ISS ≤ 15 vs ISS >15), and severe or less injury vs severe-plus injury (ISS ≤ 24 vs ISS >24).[21]

The exposure factor in this study was BMI defined as weight in kilograms divided by height in meters squared. Height and weight were obtained from the driver. If they were unable to be obtained from the driver, driver's license record would be requested.[19] BMI was considered as a continuous variable in the analysis.

Selected characteristics of the driver, crash, and environment were selected as covariates and potential confounders in the analyses. The continuous variables included driver age, vehicle age, curb weight of vehicle, and change of velocity during the crash (ΔV), measured by a computer program that reconstructs a single 2-dimensional vehicle-to-vehicle impact or a vehicle-to-large-object impact [19]. The categorical variables included driver sex, race, type of vehicle, alcohol use, drug use, seat belt use, air bag deployment, ejection, rollover, number of involved vehicles, posted speed limit, light condition, and weather condition. Driver's race was defined as white, black, other, or unknown. There were two types of vehicles: passenger car and light truck (less than 4,536kg). Alcohol use, drug use, seat belt use, ejection, and rollover were defined as yes, no, or unknown. Air bag deployment was coded as yes, no, not equipped, or unknown. Number of involved vehicles included single, two or more, and unknown. Posted speed limit was grouped into five categories: ≤ 30 mph, >30 to ≤ 50 mph, >50 to ≤ 65 mph, >65 mph, and unknown. Light condition was defined as daylight, dark, dark but lighted, other, or unknown. Weather condition was coded as no adverse condition, adverse condition, or unknown.

Statistical Analysis

The mean for continuous variables, the percentage for categorical variables, and their 95% confidence intervals (CIs) were calculated separately for male, female, and pooled data sets. The differences of mean and proportion between men and women were compared by using t-test and χ^2 test for continuous and categorical variables, respectively.

Because ISS was considered as an ordered categorical variable in this study, an ordinal logistic regression model was taken into account to address the association between ISS and BMI. The likelihood ratio test was used to test the model by using the data set without survey weight adjustment. In this test, the assumptions of proportional/parallel odds of constrained ordinal logistic regression were violated; this finding indicated that a generalized ordered logistic model should be used. To implement this model within the survey data set, with the same designs, the generalized ordered logistic model was split into four separate binary logistic models instead. For each regression model, the dependent variable was set to 0 or 1, depending on whether the ISS was less or more than a certain

cutoff (the four ISS cutoffs mentioned above). BMI was considered as an independent variable to test the linear association, whereas BMI and BMI^2 were considered as independent variables to test the curvilinear association, with risk of non-fatal injury. Male and female drivers were analyzed separately in these models; however, sex difference was examined by the same models with the use of pooled data sets (combined male and female drivers) by adding the sex variable and its interactions with BMI or BMI and BMI^2 in the models. The adjusted coefficients for risk of various severities of injury per unit increase in BMI in the sex-specific model and *p* values of interactions between sex and BMI (or BMI and BMI^2) in the pooled models were calculated in these binary logistic regression models.

All of the above regression models were performed twice with and without the inclusion of *V*: 1) the All Subjects Model, which did not include *V* as a covariate and thus included all subjects during the analysis, and 2) the *V* Model, which included *V* and thus excluded subjects for whom *V* information was missing (about 45%) during the analysis.

STATA (Version 10.0, Stata Corp, TX) was used for all statistical analyses, which were all conducted with sampling weights to estimate national representativeness. Values of $p<0.05$ (two tailed) were considered statistically significant.

RESULTS

A total of 6,580 male and 4,382 female surviving drivers were entered in the final analyses, which were weighted to represent a national sample of 2, 965, 332 male and 2, 392, 936 female drivers, respectively. The characteristics of the sample stratified by sex are presented in Table 1. The table presents the means for continuous variables and proportions for categorical variables and their 95% CIs for driver, vehicle, collision, and environmental factors. Male drivers were significantly younger, taller, heavier, and had larger BMIs than female drivers, respectively. More MVCs occurred among female drivers when driving passenger cars than among male drivers. Female drivers were also more likely to drive newer and lighter vehicles than were male drivers. Male drivers had greater percentages vehicle rollover and lower percentages of seat belt use than did female drivers. Male drivers were more likely to be involved in MVCs involving single vehicle. Male drivers were more likely to be involved in MVCs at night. No sex differences were found for age, race, alcohol use, drug use, airbag deployment, ejection, or weather conditions.

There was no significant difference in the mean ISS between injured male and female drivers. Male drivers endured a lower rate of overall injury (ISS>0, 38.1% vs. 52.2%) but higher rate of severe injury (ISS>24, 0.7% vs. 0.2%) compared with female drivers.

The results of the binary logistic models for testing the association between risk of non-fatal injury and BMI (or BMI and BMI^2 for curvilinear relations) in male drivers, female drivers, and pooled drivers in the All Subjects model (left) and the *V* Model (right) are summarized in Table 2. Covariates were adjusted in all models, including age, race, alcohol involvement, drug involvement, type of vehicle, vehicle age, curb weight, seat belt use, air bag deployed, ejection, rollover, involved vehicle number, road speed limit, light condition, weather condition, and *V* (for *V* Model). The adjusted odds ratios (ORs) derived from logistic

regression coefficients for 28 BMI points from 18 to 45 kg/m^2 are shown in Figures 1 and 2. The mean BMI of 26.0 kg/m^2 was used as the reference in male drivers (upper panel) and female drivers (lower panel) in both the All Subjects Model (Figure 1) and the *V* Model (Figure 2). In the All Subjects Model, a U-shaped association was identified between risk of moderate-plus injury (ISS>8) and obesity in male drivers (logistic coefficient of BMI= −0.4113, *p*<0.01; logistic coefficient of BMI^2=0.0075, *p*<0.01), which means that lean and obese male drivers (both ends of the BMI continuum) endured a higher risk of moderate-plus injury (ISS>8) than did normal male drivers. However for female drivers, an inverted U-shaped association was found between risk of moderate-plus injury (ISS>8) and BMI (logistic coefficient of BMI=0.4227, *p*<0.01; logistic coefficient of BMI^2=−0.0073, *p*<0.01). Obese male drivers showed much higher risks of serious-plus injury (ISS>15) and severe-plus injury (ISS>24) than normal male drivers. In the *V* Model, all the associations derived from the regression models were postulated within the same collision conditions during the MVCs. The associations between obesity and non-fatal injuries were more evident with these conditions. Obese male drivers experienced progressively increasing risks of moderate-plus injury, serious-plus injury, and severe-plus injury compared with nonobese male drivers (logistic coefficient of BMI=0.0766, 0.1470, and 0.1792, respectively; all *p*<0.05). Sex differences in the patterns of associations with obesity were observed in the risk of moderate-plus injury (ISS>8), serious-plus injury (ISS>15) and severe-plus injury (ISS>24) in both the All Subjects Model and the *V* Model. With similar directions and trends in both models, the figures highlight that the risk of non-fatal injury increased more dramatically with BMI for male drivers than for female drivers; furthermore, these sex differences increased with the severity of injury, especially after control for *V*.

DISCUSSION

In the present study, we tested the associations between obesity and non-fatal MVC injury and the related sex differences in these associations. After the analysis was controlled for potential confounding effects, including *V*, obese male drivers showed much higher risks of non-fatal injuries of various severity than did nonobese male drivers, and these risks increased with injury severity. In particular, sex differences were found in these associations such that the relationship of increasing risk of non-fatal injury with obesity was much stronger in male drivers than in female drivers.

BMI and Non-fatal Injury Severity

The associations between obesity and mortality from MVCs have been identified in previous studies; however, the relationships of obesity with injury were not well understood. Within these limited studies, all analyses were conducted for fatal and non-fatal injuries together, and the results of such studies were inconsistent. In the present study, we analyzed non-fatal injury independently and used a much larger national database compared with previous studies. We found that obese male drivers had increased risks of non-fatal moderate-plus (ISS>8), serious-plus (ISS>15), and severe-plus (ISS>24) injury compared with their nonobese counterparts. This positive association between obesity and non-fatal injury was similar to that found in Mock et al.'s study.[12] In that study, Mock et al. identified the relationship of body weight and BMI with risk of injury with ISS 9, and they found that

occupants with higher body weight and BMI had a higher risk of being injured than did lighter and leaner occupants. Although their results were similar to ours, Mock et al. included fatal injury in the study and did not conduct the analyses separately in each sex.

Our results were inconsistent with several previous studies. Boulanger et al. found that obese occupants had a statistically lower ISS than did the nonobese group (13.5 vs 14.5).[9] They explained that these small numerical differences were probably clinically irrelevant. The mean ISS in their study was much higher than in the current study, because the subjects in their study were patients from a trauma center and not drivers involved in MVCs as in the present study. In an inpatient study, Arbabi et al. found that overweight occupants had a significantly lower ISS than did lean occupants.[8] This different conclusion might have been due to their small sample size (n=189), the non-nationally representative database, or the inpatient study design.

The associations identified in the present study between obesity and non-fatal injury agrees with findings for fatal injury.[10–13] Moreover, in our previous study, we examined obesity and risk of death due to MVCs in male drivers and female drivers separately.[15] The results of the present study, which used a similar data set and study design, are consistent with that previous study for both male and female drivers. Thus, we confirmed with non-fatal injury data in present study that the increased mortality of the obese drivers was most likely due to the increased severity of their injuries or related comorbidities and not due to the difficulties of post-injury treatment of the obese victims.[8] In present study, we also compared the characteristics among obese, overweight and normal drivers, and we did not find any significant difference in the 'riskier' profiles such as vehicle age and change of velocity (V) (data not shown).

Sex Differences

In our previous study, we indicated a sex difference for the association between BMI and risk of fatality from MVCs;[15] however, whether a similar sex difference existed for the association of BMI with risk of non-fatal injury was not well understood. In the present study, we found the rate of overall non-fatal was lower but the rate of severe injury was higher in male drivers than in female drivers. This suggested that male drivers experienced more severe injuries during MVCs than female drivers. We also found that a difference in the risk of obesity-related non-fatal MVC injury did in fact exist between male and female drivers, particularly after control for V in the V Model. Obese male drivers had much higher risks of non-fatal injury compared with their nonobese counterparts than did obese female drivers. This study was also consistent the findings of our recent study about the sex difference on obesity and regional body injury, in which obese male drivers were reported to experience much higher risk of upper body injury than both obese and nonobese female drivers.[16] The reasons for these differences are still unknown. Obviously, the most frequently mentioned explanations for the increased risk of MVC injury among obese persons, such as difficulties of post-injury treatment and comorbidities, are not likely to be responsible for this sex difference because these variables should have played similar roles for both male and female obese drivers. Some factors that do differ between men and women might account for this sex difference. For example, body shape and body fat

distribution, which differ substantially between the men and women, might play an important role in the different associations of non-fatal injury with obesity. In the condition of similar body weight, the gynoid, pear-shaped pattern of obesity is most often seen in women, whereas the android, apple-shaped pattern is most commonly seen in men.[18] Wang et al. observed an increased subcutaneous fat depth associated with significantly decreased injury severity to the abdominal region among women but not among men.[17] The protection attributed to an increase in insulating tissue in the abdomen, also called the "cushion effect," was claimed by Arbabi et al.[8] This could also, in part, account for the sex difference. However, data about body shape and fat distribution were not available from the dataset except the height and weight, we could not examine the effect of body shape and fat distribution on non-fatal injury during MVCs.

Current vehicular cabins were designed to comply with the Federal Motor Vehicle Safety Standard (FMVSS) and are tested in the driver's position by using the 50th percentile male Hybrid III Crash Dummy (H3CD).[22] The body habitus of the US population has changed largely in the past two decades, and the male dummy is not appropriate for predicting the effects for females because of the different patterns of injury with obesity between men and women. Thus, the designs based on FMVSS and H3CD do not benefit most occupants. Re-designed crash test dummies and crash simulations are encouraged to account for the different effects of body shape and fat distribution on MVC injury in male and female occupants. Such re-designs would optimize vehicle designs and benefit more people.

In this study, we found that the risk of non-fatal injury increased more with the severity of injury in obese male drivers than in obese female drivers. We also found that obese male drivers were more likely to experience more severe non-fatal injury during MVCs. If fatal injury was taken into account as the most severe injury, these results would coincide with our previous study about obesity and risk of fatality.[15]

Limitations and Strengths

The results of this study should be interpreted in light of several limitations and strengths. Approximately 24% of the study population was subsequently excluded from the analyses for the following reasons: missing data on BMI, sex, and death; pregnant women; and BMI outliers (1% at both ends). Missing data accounted for the most exclusion and might have caused bias; however, there is no a priori reason to suspect that the data on the missing drivers would be differentially ascertained. Characteristics were compared between drivers with and without missing data and no significant differences were found. Second, in order to adjust for V in the regression models, 44.5% of drivers for whom V information was missing were excluded in the V Model. No difference was shown in demographic variables between drivers with or without V, but significant differences were found in some collision and environmental variables and might cause bias. Third, in the present study, due to the lack of comorbidity data in the NASS CDS, the effect of comorbidity on the association between obesity and non-fatal MVC injury could not be evaluated. Further studies are encouraged to address this hypothesis.

This is the first study to examine the effect of sex difference on the association between BMI and non-fatal MVC injury. All potential covariates and confounders from the literature

and our previous experience were included in our regression models. The updated NASS CDS data set from 2003 to 2007 was used in the present study and the large number of observations provided high statistical power. We focused only on drivers of frontal collisions and used separate analyses for men and women, which would eliminate potential differences in sex, causal pathways, and confounding factors between drivers and passengers among different collision types.

Conclusion

Obese male drivers have progressively increased risks for various severities of non-fatal injury compared with nonobese male drivers. A sex difference in the association between BMI and risk of non-fatal injury was demonstrated for the risks of moderate-plus (ISS>8), serious-plus (ISS>15), and severe-plus (ISS>24) injury showing that obese male drivers were more likely than obese female drivers to experience a higher risk of non-fatal injury compared with their nonobese counterparts. This study increases our understanding of two leading health issues in the United States. Our findings will provide testable hypotheses for future studies and should be considered during high-risk cohort prediction, obesity reduction, vehicle design, auto insurance policy constitution, and safety evaluation and measurement.

Acknowledgments

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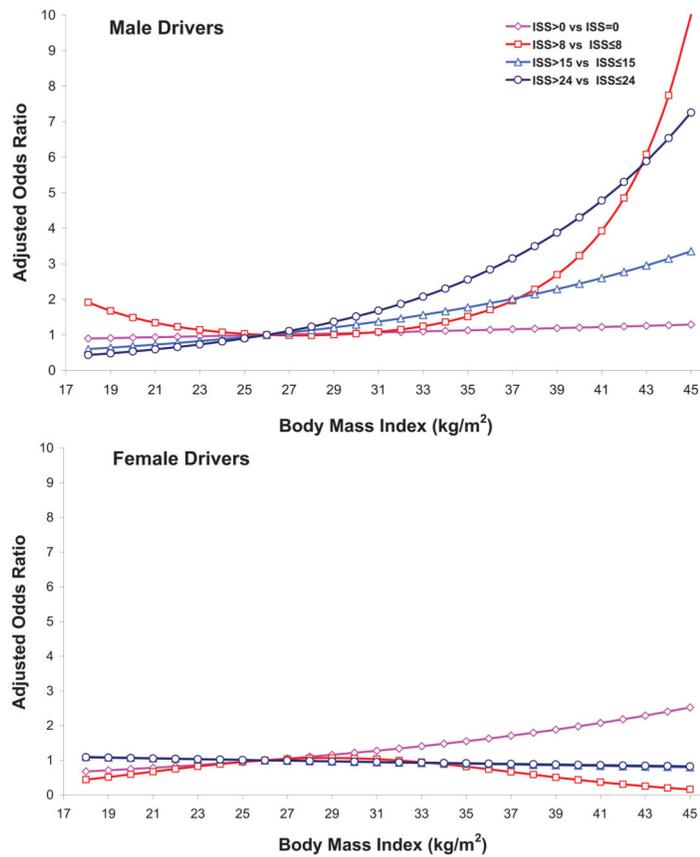
Figure 1.
Predicted adjusted odds ratios (ORs) for the risk of non-fatal injury by BMI in the All Subjects Model. A mean BMI of 26.0 kg/m^2 was considered as the reference. Adjusted odds ratios for each BMI point were calculated from coefficients from 18 to 45 by using the mean BMI as the reference. *V* was not included in the models, so all subjects were included in the analyses. ISS = Injury Severity Score. [Male model: N=6,279, population size=2,840,932; female model: N=4,190, population size=2,318,605; pooled model, N=10,524, population size= 5,165,348]
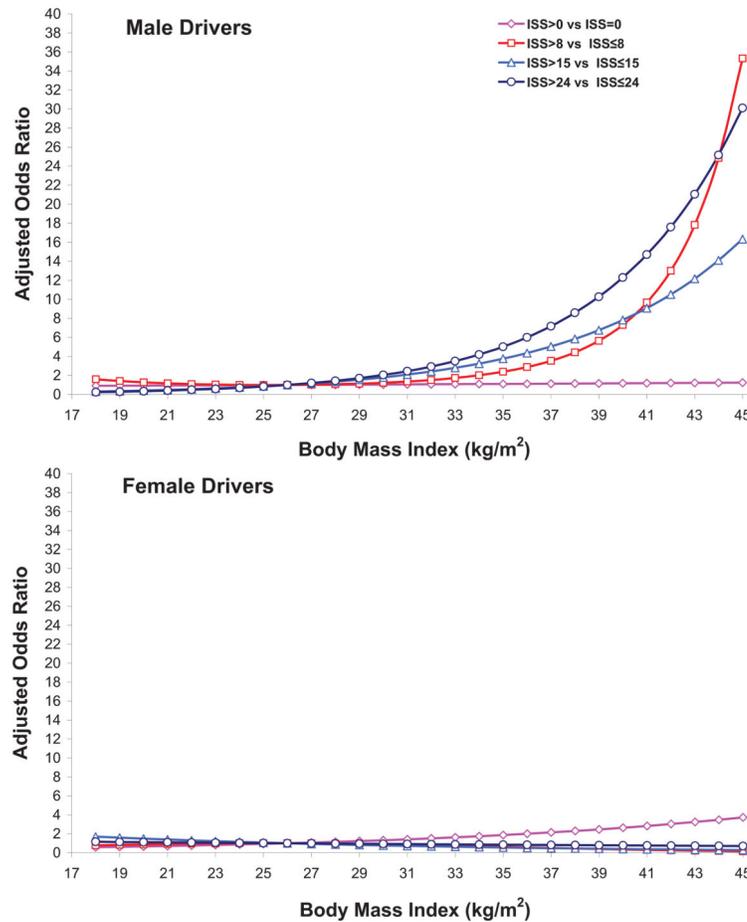
Figure 2.
Predicted adjusted odds ratios (ORs) for the risk of non-fatal injury by BMI in the V Model. A mean BMI of 26.0 kg/m² was considered as the reference. Adjusted odds ratios for each BMI point were calculated from coefficients from 18 to 45 by using the mean BMI as the reference. *V* was included in the models, so the subjects without *V* information were excluded in the analyses. ISS = Injury Severity Score. [Male model: N=3,422, population size=1,402,702; female model: N=2,508, population size=1,328,072; pooled model, N=5,948, population size=2,733,366]

Table 1

Characteristics of the sample of surviving drivers involved in motor vehicle crashes

	Male	Female	Pooled
Sample Size	6,580	4,382	10,962
Weighted Size	2,965,332	2,392,936	5,358,268
Mean (95% CI)			
Age, y	36.6 (35.8, 37.3)	38.5 (37.2, 39.7)[*]	37.4 (36.6, 38.2)
Height, cm	178.0 (177.2, 178.9)	164.4 (163.5, 165.3)[**]	171.9 (171.4, 172.5)
Weight, kg	84.6 (83.9, 85.3)	69.2 (66.7, 71.8)[**]	77.7 (76.7, 78.8)
BMI, kg/m^2	26.7 (26.5, 26.9)	25.6 (24.9, 26.2)[**]	26.2 (25.9, 26.4)
ISS (the injured)	2.9 (2.2, 3.6)	2.6 (2.2, 2.9)	2.7 (2.2, 3.2)
Vehicle Age, y	7.9 (7.5, 8.4)	7.1 (6.5, 7.8)[*]	7.6 (7.1, 8.0)
Curb Weight, kg	1570.6 (1520.4, 1620.8)	1436.4 (1380.9, 1491.8)[**]	1510.4 (1483.7, 1537.1)
Total V, mph	21.2 (20.6, 21.8)	20.7 (19.5, 22.0)	21.0 (20.2, 21.7)
Percentage (95% CI)			
Non-fatal Injury Severity			
Overall Injury (ISS>0)	38.1 (34.5, 41.8)	52.2 (44.2, 60.0)[**]	44.4 (39.0, 49.9)
Moderate Injury (ISS>8)	3.0 (2.0, 4.5)	2.8 (2.2, 3.4)	2.9 (2.3, 3.6)
Serious Injury (ISS>15)	1.2 (0.8, 1.8)	0.9 (0.6, 1.2)	1.1 (0.8, 1.4)
Severe Injury (ISS>24)	0.7 (0.3, 1.3)	0.2 (0.2, 0.4)[**]	0.5 (0.3, 0.8)
Passenger Car	59.1 (56.7, 61.5)	72.0 (68.7, 75.0)[**]	64.8 (62.2, 67.4)
Seat Belt Used	77.7 (74.0, 81.0)	84.5 (80.3, 87.9)[**]	80.7 (77.0, 83.9)
Air Bag Deployed	35.7 (32.8, 38.8)	38.7 (34.8, 42.8)	37.1 (34.2, 40.0)
Rollover	6.0 (4.6, 7.7)	3.3 (2.2, 4.8)[**]	4.8 (3.7, 6.2)
Single Vehicle Involved	37.8 (31.7, 44.3)	28.9 (25.0, 33.1)[*]	33.8 (30.1, 37.8)
Daylight Condition	60.9 (56.3, 65.2)	70.0 (66.5, 73.4)[**]	65.0 (61.4, 68.4)

[*]
p<0.05;

[**]
p<0.01; comparisons between men and women were made with weighted t-test for continuous variables and χ^2 for categorical variables.

Abbreviations: BMI = body mass index; ISS = Injury Severity Score. Data are from the 2003 to 2007 National Automotive Sampling System Crashworthiness Data System.

Table 2

Results of the binary logistic regression models testing the association between risk of non-fatal injury and BMI

	All Subjects Model[a]			V Model[a]		
	Male (coefficient)[c]	Female (coefficient)[c]	Difference (P value)[d]	Male (coefficient)[c]	Female (coefficient)[c]	Difference (P value)[d]
ISS>0 vs ISS=0[b], Overall Injury						
Linear						
BMI	0.0134	0.0487[+]	P=0.184	0.0114	0.0693[+]	P=0.243
Curvilinear						
BMI	−0.1375	−0.0230	P=0.166	−0.4060	0.2222	P=0.072
BMI^2	0.0026	0.0013	P=0.290	0.0073	−0.0027	P=0.070
ISS>8 vs ISS ≤8[b], Moderate Injury						
Linear						
BMI	0.0349	0.0043	P=0.444	0.0766[*]	−0.0332	P=0.067
Curvilinear						
BMI	−0.4113[**]	0.4227[**]	P<0.01	−0.4585[*]	0.2470	P<0.01
BMI^2	0.0075[**]	−0.0073[**]	P<0.01	0.0091[*]	−0.0049	P<0.01
ISS>15 vs ISS ≤15[b], Serious Injury						
Linear						
BMI	0.0637[*]	−0.0118	P<0.05	0.1470[**]	−0.0663	P<0.01
Curvilinear						
BMI	−0.1725	0.0265	P=0.520	−0.0490	0.0572	P=0.839
BMI^2	0.0039	−0.0007	P=0.398	0.0032	−0.0022	P=0.504
ISS>24 vs ISS ≤24[b], Severe Injury						
Linear						
BMI	0.1043[**]	−0.0101	P<0.05	0.1792[**]	−0.0182	P<0.01
Curvilinear						
BMI	−0.0330	−0.2883	P=0.233	0.0405	−0.3175	P=0.116
BMI^2	0.0023	0.0048	P=0.348	0.0023	0.0052	P=0.194

Abbreviations: BMI = body mass index; ISS = Injury Severity Score; V = change of velocity during the crash. Data are from the 2003 to 2007 National Automotive Sampling System Crashworthiness Data System.

[a] The analysis was limited to drivers who were involved in frontal collisions only. V was not included in the All Subjects Model but was included in the V Model; therefore, the subjects with V not available were excluded during the analysis for the V Model. The outcome of the model was injury severity (defined by ISS), and the exploratory factor was BMI for linear and BMI & BMI^2 for curvilinear. Covariates in the model were age, race, alcohol involvement, drug involvement, type of vehicle, vehicle age, curb weight, seat belt use, air bag deployed, ejection, rollover, involved vehicle number, road speed limit, light condition, weather condition, and V (for V Model); sex was included in the pooled model. All categorical variables were conducted as dummy variables. All reference groups of these variables were first grouped in the variable as the default.

[b] Four cutoffs of ISS were used to define injury severity: ISS=0 vs ISS>0, ISS ≥8 vs ISS>8, ISS ≥15 vs ISS>15, and ISS ≥24 vs ISS>24. The sex difference was evaluated in the pooled model by adding interactions between sex and BMI (BMI and BMI^2) in the model, and then male and female drivers were analyzed by logistic regression models separately.

[c] Coefficients from the logistic regression models are presented.

[+] $p<0.10$;

[*] $p<0.05$;

[**] $p<0.01$.

[d] Interactions between BMI (and BMI^2) and sex were tested in the pooled model and the p values of these interactions are presented.