Effect of BMI on the Risk of AIS 3+ Injury Outcome in Frontal Crashes With & Without Seat Belt

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INTRODUCTION

In the United States, around 45,000 people died and more than 3 million people got injured in motor vehicle accidents. [1] Obese population in the United States are increasing in recent decades. [2] The influence of obesity on the injury risks and injury distribution in motor-vehicle crashes is not fully understood. [3]

Frontal crashes are the most frequent car crashes in real world.[4] Seatbelt has effectively protected occupant in traffic incidents. However, few of previous studies have shown the relationship between obesity and injury risks in occupants with or without seatbelts. In this study, body mass index (BMI) was applied to investigate its influence on serious injury distributions and risks in different body regions in frontal car crash scenarios.

METHODS

Real-World Dataset

Data from 2004 to 2013 Crashworthiness Data System (CDS) of the National Automotive Sampling System (NASS) maintained by National Highway Traffic Safety Administration were used. CDS contains data on occupant injuries, vehicle damage and injury sources. Serious injuries in NASS-CDS were selected according to the Abbreviated Injury Scale (AIS).

Variable Selection

Accident data selection procedure of this analysis is demonstrated in Fig. 1.

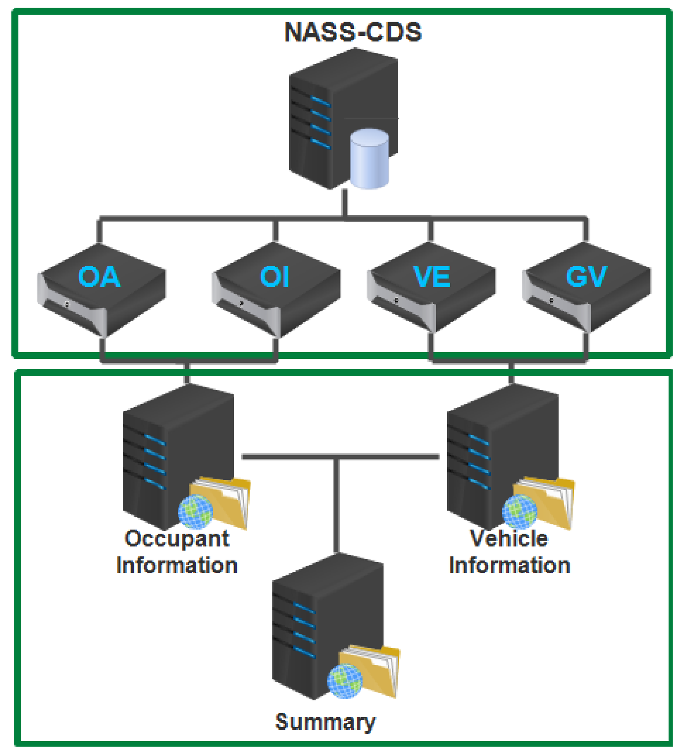

Fig. 1: variable selection flowchart

The following selection criteria were applied for both drivers and front seat passengers:

- Frontal crashes;
- Vehicles with model year > 1999 and known vehicle types;
- Passenger cars and trucks only;
- Occupants aged 16 years or older;
- Occupants with known height, weight, and gender;
- Cases with known belt and airbag usage information.
- Cases with AIS values

Summary of total injuries and AIS3+ injuries is tabulated in Table 1.

Table 1:Number of drivers and front passengers in the US NASS data

Accident year	No. of injuries	No. of AIS3+ injuries
2004-2013	53,766	5,773

Statistics Approach: Injury Distribution and Logistic regression

To study the effect of BMI on frontal impact injuries, two approaches were adopted in the current study.

(a) Injury distribution: Accident cases involving AIS3+ cases were considered for this study. AIS3+ injury distributions are calculated by dividing the number of AIS3+ injuries within four selected BMI groups by the total number of AIS3+ injuries. The equation is shown below:

$$\text{AIS3+ Injury Distribution for "X" BMI group (or for "Y" body region)} = \frac{\text{Number of AIS3+ Injuries [for "X" BMI group or "Y" body region]}}{\text{Number of AIS3+ Injuries [for all body region]}}$$

(b) Logistic regression: All parameters were presented as continuous variables or as categorical variables (Table 2). Weighting factors obtained from database were normalized and applied to the regression analysis. The forward Wald method was performed to evaluate the contribution of each parameter to the regression model.

Predictor	Level
Age (years)	Continuous
Gender	Male,female
Height (m)	Continuous
Weight (kg)	Continuous
BMI (kg/m^2)	Continuous
Airbag	Deployed,non-deployed
Seatbelt	Yes or No
Vehicle Type	Passenger car or Truck
Curb Weight	Continuous
Delta-V	Continuous
Occupant Role	Driver or Passenger
Seat position	First,Second,...,Fifth
Model Year	Continuous

Table 2: predictors used in the regression models

RESULTS

Injury Distribution

Of all AIS3+ injuries, distributions according to different body regions (head, neck thorax, abdomen, lower extremity and upper extremity) are shown in Fig. 2. Distributions according to four selected BMI groups are shown in Fig. 3.

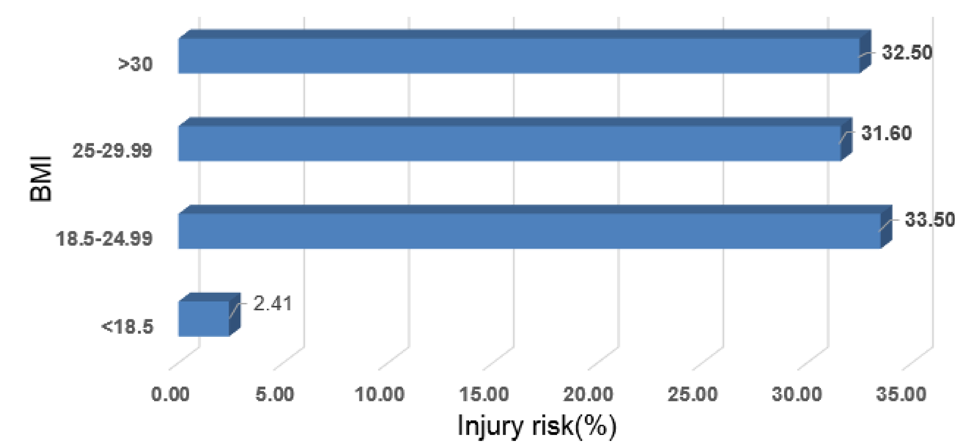

Fig. 3: AIS3+ injury distribution based on BMI group

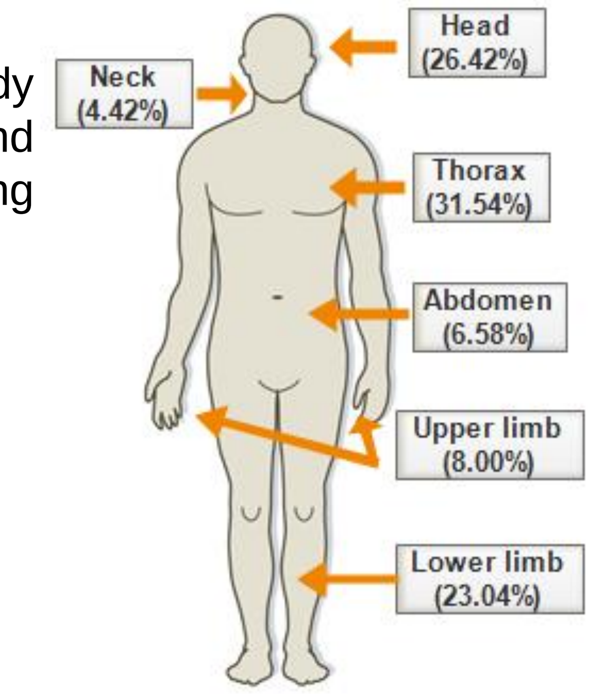

Fig. 2: AIS3+ injury distribution based on body region

All occupants were divided into two groups: occupant with and without seatbelt. Then, within these two groups, injury distributions are shown in Fig. 4.

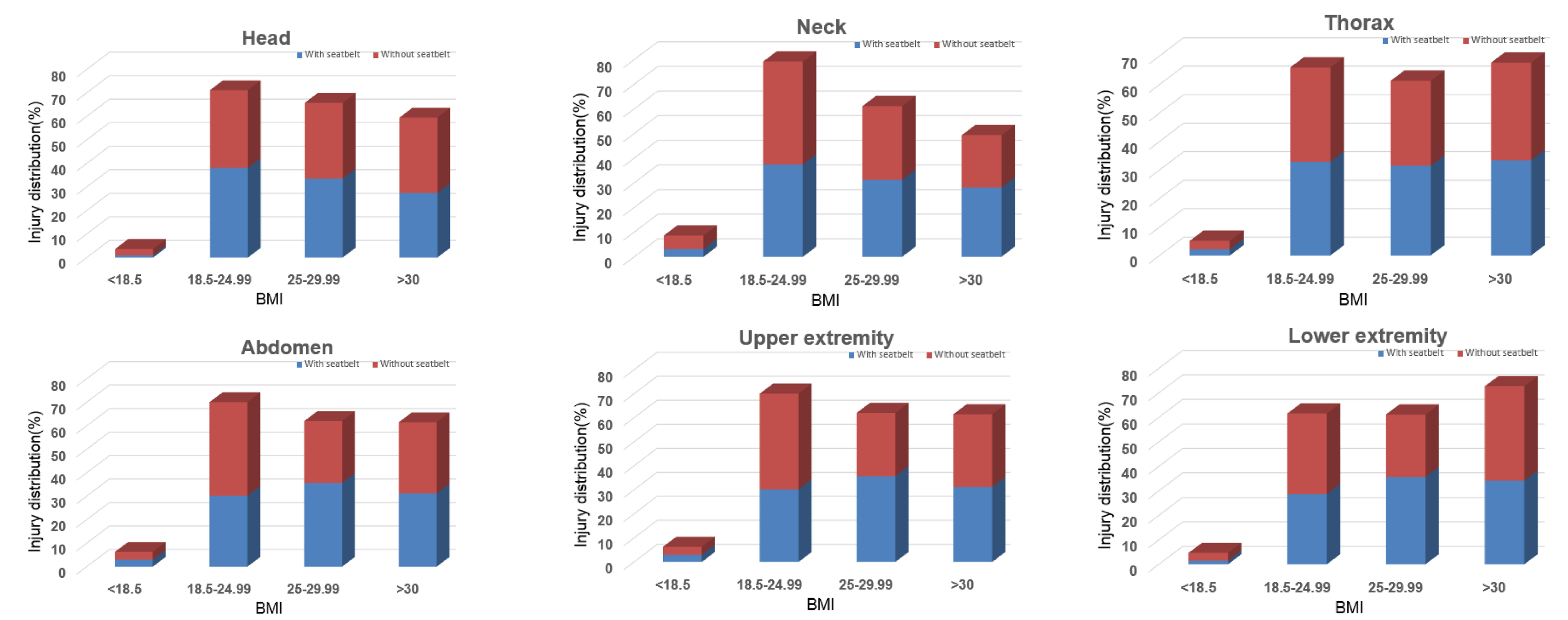

Fig. 4: AIS3+ injury distribution of two groups: occupant with seatbelt and without seatbelt

Logistic regressions using SPSS show that BMI is significant predictors of AIS3+ injury for head, thorax and lower extremities (Table 3). Fig. 6 shows the injury risk for head, thorax, and lower extremity as a function of BMI. For head injury, all data were with respect to an occupant as driver, 35 years old, first row and model 2013. For thorax injury, it was with respect to the occupant as driver, 35 years old, Delta-V 27km/h and model 2013. For lower extremities injury, it was relative to 35 years old, first row and Delta-V 27km/h.

Parameter	Head	Neck	Thorax	Abdomen	Upper extremity	Lower extremity
Age	<0.0001(1.010)*	<0.0001(1.027)*	<0.0001(1.013)*	0.006(1.013)*	<0.0001(1.021)*	<0.0001(1.012)*
Gender	<0.0001(0.512)*	0.095(-)	<0.0001(0.563)*	0.047(0.693)*	0.589(-)	0.152(-)
BMI	0.021(1.013)*	0.960(-)	0.017(0.987)*	0.142(-)	0.770(-)	<0.0001(1.020)*
Airbag	0.964(-)	0.033(0.677)*	0.246(-)	0.147(-)	<0.0001(2.438)*	<0.0001(1.969)*
Seatbelt	<0.0001(0.271)*	<0.0001(0.407)*	<0.0001(0.579)*	<0.0001(0.475)*	<0.0001(0.560)*	<0.0001(0.299)*
Vehicle Type	0.713(-)	0.001(0.537)*	0.557(-)	0.775(-)	0.434(-)	0.106(-)
Curb Weight	0.460(-)	0.625(-)	0.492(-)	0.132(-)	0.799(-)	0.054(-)
Delta-V	0.537(-)	0.095(-)	<0.0001(1.008)*	<0.0001(1.020)*	<0.0001(1.018)*	<0.0001(1.020)*
Occupant Role	<0.0001(0.666)*	0.676(-)	<0.0001(1.644)*	0.362(-)	0.001(0.615)*	0.533(-)
Seat Position	<0.0001(0.117)*	0.733(-)	0.403(-)	0.914(-)	0.369(-)	<0.0001(16.944)*
Model Year	<0.0001(1.087)*	0.399(-)	<0.0001(1.184)*	0.031(1.059)*	0.823(-)	0.272(-)

Table 3: Parameter P value and odds ratio(within brackets); asterisk means this parameter is significant.

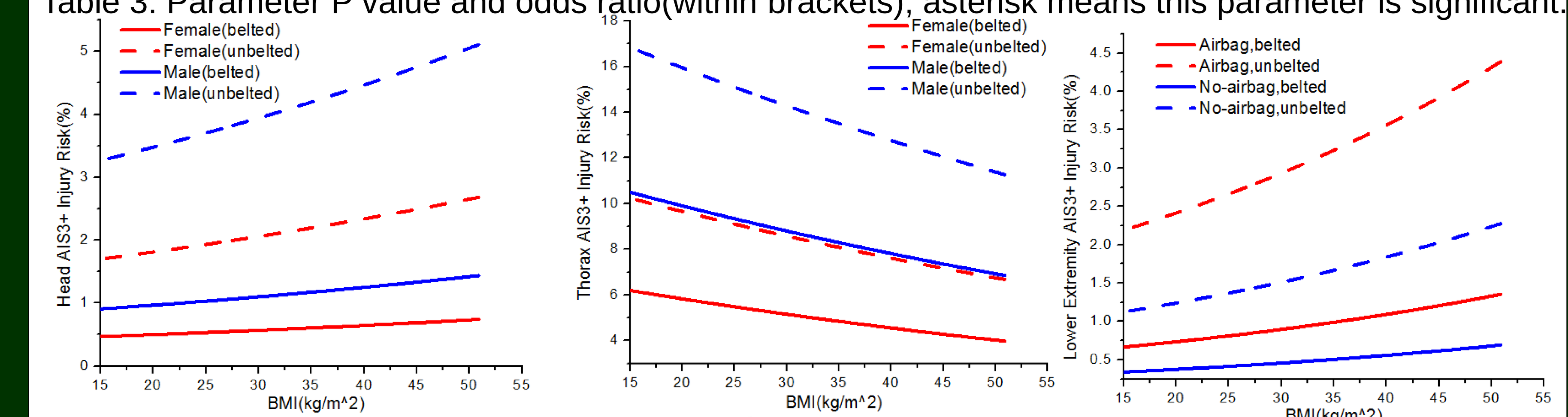

Fig. 6: Effects of varying BMI from 15 to 45 kg/m^2 on AIS3+ injury risk in frontal crashes for body regions.

CONCLUSIONS

From the injury distribution, the highest AIS3+ injury percentage happened at thorax and lowest at neck region. Underweight people (BMI<18.5) has lowest injury distribution. According to the logistic regression model:

- BMI represents the fourth significant parameter in AIS3+ head and thorax injuries and the second significant parameter in AIS3+ lower extremity injury. Increasing BMI increases the risk of head and lower extremity injury in frontal crashes, decreases the risk of thorax injury in frontal crashes;
- Several findings were also affected by interactions with gender, age, occupant role (driver or passenger), airbag usage, seatbelt usage, seat position, Delta-V and vehicle model year;
- Whether or not an occupant wearing seatbelt has significant influence on the risk of injury. For head and thorax, the injury risk of male and female without seatbelt are higher than those with seatbelt use;
- The effect of BMI on lower extremity injury in frontal crashes were not affect by gender.

ACKNOWLEDGEMENT AND REFERENCES

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