



Impact of obesity on the severity of trauma in patients injured in pedestrian traffic accidents

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Purpose: Studies on the relationship between obesity and injuries, especially those sustained in pedestrian traffic accidents, are lacking. We aimed to assess the effects of obesity on the severity of injury at the time of admission to the emergency room in patients who experienced pedestrian traffic accidents.

Methods: This study included trauma patients registered in the Korean Trauma Database from July 1, 2018 to December 31, 2020, whose mechanism of injury was pedestrian traffic accidents and who were treated at a single institution. Those aged below 15 years were excluded. Patients were assigned to nonobese and obese groups based on a body mass index of 25 kg/m². An Injury Severity Score of 25 or greater was considered to indicate a critical injury.

Results: In total, 679 cases of pedestrian traffic accidents were registered during the study period, and 543 patients were included in the final analysis. Of them, 360 patients (66.3%) and 183 patients (33.7%) were categorized as nonobese and obese, respectively. The median age was significantly higher in the nonobese group than in the obese group (60 vs. 58 years). Multivariate analysis demonstrated that the odds ratio for critical injury in obese patients was 1.59 (95% confidence interval, 1.01–2.48) compared with nonobese patients.

Conclusions: Obesity affected the likelihood of sustaining severe injuries in pedestrian traffic accidents. Future studies should analyze the effects of body mass index on the pattern and severity of injuries in patients with more diverse injury mechanisms using large-scale data.

Keywords: Traffic accidents; Pedestrians; Injury Severity Score; Obesity; Body mass index

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INTRODUCTION

Obesity is a risk factor for ischemic heart disease, cerebrovascular disease, diabetes mellitus, hypertension, dyslipidemia, and several malignant neoplasms [1–6]. The prevalence of overweight and

obesity is increasing in both developed and developing countries. This can lead to an increase in comorbidities, which in turn imposes an increased socioeconomic burden. Thus, obesity has been identified as a major public health problem [7]. In South Korea, the prevalence of obesity in adults aged age 19 years and

above increased by 2.9 percentage points from 31.7% in 2007 to 34.6% in 2018 [8]. Many studies have analyzed the mechanisms underlying obesity, its relationship with medical diseases, and its clinical significance. However, there is a relative lack of knowledge regarding the relationship between obesity and injuries. Most studies that analyzed the correlation between obesity and injuries from traffic accidents focused on car accidents and reported that obesity had negative effects on outcomes [9,10]. However, few studies have analyzed the effects of obesity on injuries sustained in pedestrian traffic accidents. Therefore, this study aimed to assess the effects of different levels of obesity on injury severity at the time of admission to the emergency room among patients who experienced pedestrian traffic accidents.

METHODS

Ethical statements

The study was approved by the Institutional Review Board of Gachon University Gil Medical Center with a waiver for the need for informed consent (No. GAIRB2021-228).

Data collection

The study was performed at Gachon University Gil Medical Center, a 1,500-bed tertiary general hospital, located in Incheon, Korea. Gachon University Gil Medical Center has been designated as a regional emergency medical and trauma center; approximately 80,000 patients visit this hospital annually, including 20,000 trauma patients. Institutions selected to receive support for regional trauma center installation are required to input data into the Korean Trauma Data Bank (KTDB). Patients registered in the KTDB include those who present to the emergency room or trauma resuscitation room of participating hospitals, and those with S- and T-codes were eligible for the study. Patients who were discharged home without being admitted were excluded [11].

Patient selection

Trauma patients registered in the KTDB from July 1, 2018, to December 31, 2020 who experienced pedestrian traffic accidents and were treated at Gil Medical Center were included in this study. Patients under 15 years of age were excluded, as were those who died at the time of admission to the emergency room or in the emergency room, because those accidents were expected to be fatal regardless of the patient's characteristics, including body mass index (BMI), which would have had caused serious bias in the study. Patients whose BMI or Injury Severity Score (ISS) was unknown were also excluded.

Definition of variables

Data were collected from the KTDB on the following parameters: sex, age, time of injury, transport via public ambulance, suspicion of alcohol consumption, type of collision vehicle, initial vital signs and mental status upon emergency department (ED) arrival, blood transfusion, whether an emergent procedure or operation was performed, Abbreviated Injury Scale (AIS) score for each body part, intensive care unit (ICU) stay (day), total hospital stay (day), duration of mechanical ventilation, complications during hospitalization, and hospitalization results.

BMI is a universal criterion used to diagnose obesity [12]. According to the World Health Organization Asian-Pacific Region guidelines and the definitions used by the Korean Society for the Study of Obesity, BMI values greater than 23 kg/m² and 25 kg/m² are defined as overweight and obesity, respectively, in Asian populations, including Koreans [13]. Thus, patients with a BMI less than 25 kg/m² were assigned to the nonobese group, while those with a BMI greater than 25 kg/m² were included in the obese group.

The AIS is an anatomy-based coding system first proposed in 1971 that is used to classify and describe the severity of trauma [14]. The AIS score ranges from 1 to 6, and a score of 9 is defined as "not further specified." As described in previous studies, an AIS score of greater than 3 in certain body parts indicates a severe injury [15,16]. The ISS was first proposed in 1974 and is widely used to estimate the severity of injuries [17]. In studies that analyzed the ISS as a prognostic factor in trauma patients, the ISS was divided into mild (< 9), moderate (9–15), severe (16–25), and profound (> 25) or minor (< 4), moderate (4–8), serious (9–15), severe (16–24), and critical (> 24). In our study, to focus on the effects of obesity in more severe injuries, trauma injuries with an ISS greater than 25 were considered critical, as in other studies [18–20].

Statistical methods

The chi-square test was performed to compare discrete dependent variables. For continuous dependent variables, the median and interquartile range (IQR) were calculated, and the Mann-Whitney U-test was used to compare the differences. Additionally, multivariate logistic regression analysis was performed to identify factors associated with the dependent variables. Multivariate logistic regression with the use of backward elimination was performed on variables that showed associations with P-values less than 0.20 in univariate logistic regression or were deemed clinically significant. SPSS ver. 18.0 (SPSS Inc., Chicago, IL, USA) was used to perform all statistical analyses, and a P-value of less than

0.05 was considered to indicate statistical significance.

RESULTS

A total of 2,318 traffic accident patients presented to the hospital from July 2018 to December 2020. Among these patients, 679 had experienced pedestrian traffic accidents. According to the exclusion criteria, 42 patients aged below 15 years and 36 who died at the time of arrival in the emergency room or in the emergency room were excluded. Fifty-eight patients whose BMI and ISS values were not recorded were also excluded, as this information was essential for the analysis. A total of 543 patients were included in the analysis and were divided into nonobese (360 patients, 66.3%) and obese patients (183 patients, 33.7%) (Fig. 1).

The proportion of men was slightly greater in the obese group (56.8%) than in the nonobese group (50.3%); however, no significant difference was observed ($P=0.148$). In contrast, the age of the patients was significantly higher in the nonobese group (median, 60 years; IQR, 47–72 years) than in the obese group (median, 58 years; IQR, 45–68 years; $P=0.001$). However, no significant difference was observed in the time of injury, suspicion of alcohol consumption, and type of collision vehicle between the two groups. Mental status upon arrival at the emergency room was assessed using the Glasgow Coma Scale (GCS). The proportion of patients with a GCS score <9 was higher in the obese group than in the nonobese group (19.4% vs. 10.9%), suggesting

that the level of consciousness was significantly lower in the obese group ($P=0.034$). Vital signs were also not statistically significantly different between the two groups, except for the pulse rate. The median pulse rates were 86 beats per min (bpm; IQR, 75–99 bpm) and 97 bpm (IQR, 77–108 bpm) in the nonobese and obese groups, respectively, but the difference was not clinically significant. The revised trauma score was calculated based on the patient’s information at the time of admission, and the obese group showed significantly lower scores than the nonobese group ($P=0.021$). The AIS score was significantly different in the head area between the two groups. Severe head injuries were significantly more common in the obese group (86.2%) than in the nonobese group (67.4%, $P=0.005$). Severe abdominal injuries were less frequently encountered in the obese group (51.2%) than in the nonobese group (63.3%); however, the difference was not statistically significant (Table 1).

With regard to the management provided in the ED and outcomes, the proportion of patients who required red blood cell and fresh frozen plasma transfusion was significantly higher in the obese group (24.6% and 14.8%, respectively) than in the nonobese group (16.7% and 7.5%, respectively; $P=0.027$ and $P=0.008$, respectively). Moreover, more patients in the obese group underwent emergent procedures or operations (14.9% vs. 18.6%) and were admitted to the ICU (44.7% vs. 52.5%) than those in the nonobese group; however, the differences were not statistically significant ($P=0.153$ and $P=0.088$, respectively). After hospitalization, the obese group stayed longer in the ICU than the nonobese group (median, 3.2 days vs. 5.0 days; $P=0.002$) and had a longer duration of hospitalization (median, 11.9 days vs. 14.6 days; $P<0.001$). However, no significant differences were observed in outcomes, including the mortality rate, between the two groups ($P=0.774$) (Table 2).

Age, sex, time of injury, suspicion of alcohol consumption, and type of collision vehicle were included in the multivariate analysis to assess the difference in the likelihood of sustaining a critical injury according to obesity status. The final model was selected using the backward elimination method. After adjusting for age and sex, the odds ratio (OR) for critical injury in the obese group was 1.59 (95% confidence interval [CI], 1.01–2.48) compared with the nonobese group. Furthermore, the OR for critical injury was 1.74 (95% CI, 1.10–2.74) in male patients (Table 3). However, no statistically significant difference was found between the obese group and the nonobese group for the risk of injuries with an ISS >15 .

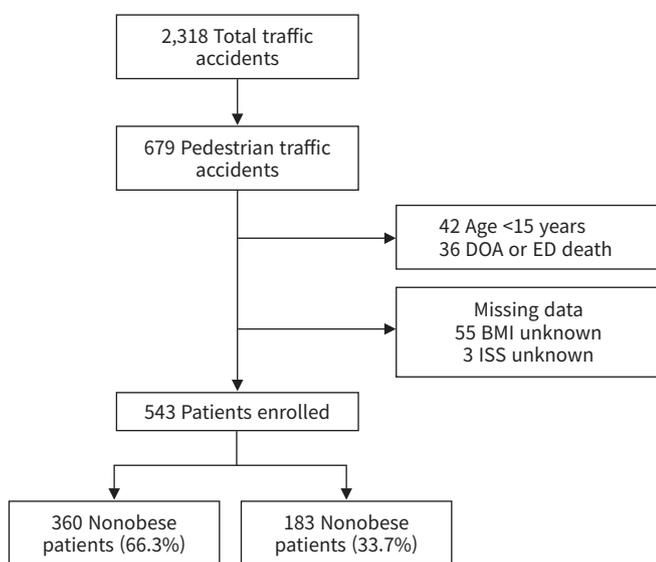


Fig. 1. Flow diagram of the patient selection and exclusion process. DOA, dead on arrival; ED, emergency department; BMI, body mass index; ISS, Injury Severity Score.

Table 1. General characteristics, mental status, vital signs, and AIS scores of patients with pedestrian injuries admitted via the emergency department

Variable	Total (n=543)	Nonobese ^{a)} (n=360)	Obese ^{b)} (n=183)	P-value
Male sex	285 (52.5)	181 (50.3)	104 (56.8)	0.148
Age (yr)	60 (47–72)	62 (49–74)	58 (45–68)	0.001
Time of injury				0.189
00:00–08:00	127 (23.4)	78 (21.7)	49 (26.8)	
08:00–16:00	236 (43.5)	154 (42.8)	82 (44.8)	
16:00–24:00	180 (33.2)	128 (35.6)	52 (28.4)	
Transportation by public ambulance	518 (95.4)	343 (95.3)	175 (95.6)	0.854
Suspicion of alcohol consumption	77 (14.2)	52 (14.4)	25 (13.7)	0.805
Type of collision vehicle				0.476
Car	460 (84.7)	304 (84.4)	156 (85.3)	
Bicycle	7 (1.3)	6 (1.7)	1 (0.6)	
Motorcycle	29 (5.3)	22 (6.1)	7 (3.8)	
Others	28 (5.2)	16 (4.4)	12 (6.6)	
Unknown	19 (3.5)	12 (3.3)	7 (3.8)	
Glasgow Coma Scale (n=495)				0.034
≥14	391 (79.0)	270 (81.8)	121 (73.3)	
9≤ & <14	36 (7.3)	24 (7.3)	12 (7.3)	
<9	68 (13.7)	36 (10.9)	32 (19.4)	
Systolic blood pressure (mmHg) (n=536)	137 (116–160)	137 (117–161)	136 (114–158)	0.196
Diastolic blood pressure (mmHg) (n=536)	84 (71–96)	84 (72–96)	85 (71–96)	0.598
Pulse rate (bpm) (n=540)	86 (75–99)	84 (74–95)	91 (77–108)	<0.001
Respiratory rate (breaths/min) (n=540)	20 (18–22)	20 (18–21)	20 (18–22)	0.117
Body temperature (°C) (n=540)	36.5 (36.0–36.8)	36.5 (36.0–36.8)	36.5 (36.1–36.9)	0.048
Revised trauma score (n=489)	7.8408 (7.8408–7.8408)	7.8408 (7.8408–7.8408)	7.8408 (6.904–7.8408)	0.021
Severe body part injury (AIS≥3 in AIS≥1)				
Head (n=203)	149 (73.4)	93 (67.4)	56 (86.2)	0.005
Thorax (n=175)	128 (73.1)	82 (73.9)	46 (71.9)	0.774
Abdomen (n=90)	52 (57.8)	31 (63.3)	21 (51.2)	0.249
Spine (n=92)	15 (16.3)	11 (19.0)	4 (11.8)	0.367
Upper extremity (n=119)	6 (5.0)	0 (0.0)	6 (13.0)	0.002
Lower extremity (n=299)	140 (46.9)	92 (46.7)	48 (47.1)	0.953

Values are presented as number (%) or median (interquartile range).

AIS, Abbreviated Injury Scale; bpm, beats per minute.

^{a)}Body mass index <25 kg/m². ^{b)}Body mass index ≥25 kg/m².

DISCUSSION

The severity of injury according to the accident mechanism seems to be affected by various physiological and biomechanical factors (e.g., change in speed at the time of collision, type of collision object, protective equipment, and collision location). There is a lack of research exploring the relationships among patient body type, specific damage mechanisms, and the severity of injuries. In general, previous studies have reported that obesity negatively affects trauma patients; however, those studies used different methods of research and reported inconsistent findings [9,10]. Thus, there is no clear consensus on the effects of obesity

in trauma patients. In this study, we adjusted for several variables that can affect the severity of injuries in pedestrian traffic accidents. The OR of critical injury in the obese group was 1.59 (95% CI, 1.01–2.48), reflecting a significantly higher risk than that in the nonobese group.

In a study on survivor drivers of passenger cars who experienced a motor vehicle crash injury, obese male drivers were more likely to have a higher ISS than nonobese male drivers [10]. Similar to our method, that study excluded patients who died in the emergency room and then analyzed the severity of injury. However, the study participants were passengers, not pedestrians as in our study. In that study, a stratified analysis according to sex and

Table 2. Management performed at the emergency department and outcomes

Variable	Total (n=543)	Nonobese ^{a)} (n=360)	Obese ^{b)} (n=183)	P-value
Transfusion of red blood cell	105 (19.3)	60 (16.7)	45 (24.6)	0.027
Transfusion of fresh frozen plasma	54 (9.9)	27 (7.5)	27 (14.8)	0.008
Emergent procedure or operation	84 (15.5)	50 (14.9)	34 (18.6)	0.153
Admission to intensive care unit	257 (47.3)	161 (44.7)	96 (52.5)	0.088
Intensive care unit days (n=257)	3.6 (1.8–8.6)	3.2 (1.5–7.0)	5.0 (2.2–13.1)	0.002
Total hospital days (n=527)	12.9 (6.9–21.7)	11.9 (6.0–20.0)	14.6 (8.9–28.0)	<0.001
Mechanical ventilation days (n=118)	3.5 (0.78–11.2)	2.7 (0.4–10.6)	5.2 (2.2–12.5)	0.097
Complication during admission (n=529)	58 (11.0)	37 (10.3)	21 (11.5)	0.669
Admission result (n=527)				0.774
Discharge	124 (22.8)	87 (24.2)	37 (20.3)	
Transfer	357 (65.8)	234 (65.0)	123 (67.2)	
Expire	46 (8.5)	28 (7.8)	18 (9.8)	

Values are presented as number (%) or median (interquartile range).

^{a)}Body mass index <25 kg/m². ^{b)}Body mass index ≥25 kg/m².

Table 3. Risk factors for critical injury (Injury Severity Score ≥25) in pedestrian traffic accidents

Variable	Unadjusted			Adjusted		
	OR	95% CI	P-value	OR	95% CI	P-value
Obesity (BMI ≥25 kg/m ²)	1.60	1.02–2.49	0.038	1.59	1.01–2.49	0.044
Age (yr)	1.00	0.98–1.10	1.011	1.00	0.99–1.01	0.527
Male sex	1.73	1.10–2.70	0.016	1.74	1.10–2.75	0.018
Time of injury						-
16:00–24:00	Reference					
00:00–08:00	1.17	0.67–2.05	0.578			
08:00–16:00	0.80	0.48–1.32	0.375			
Suspicion of alcohol consumption (yes)	0.87	0.46–1.65	0.676			-
Type of collision vehicle						-
Car	Reference					
Bicycle	0.72	0.09–6.10	0.767			
Motorcycle	0.70	0.24–2.05	0.511			
Others	0.72	0.25–2.14	0.561			
Unknown	2.00	0.74–5.43	0.170			

OR, odds ratio; CI, confidence interval; BMI, body mass index.

obesity was conducted, and obesity only had detrimental effects on injury severity in male patients. In our study, the OR for critical injury was higher in men than in women regardless of BMI, and there was no interaction between sex and BMI in relation to the risk of critical injury.

In another study that analyzed the relationship between obesity and severity of injury in blunt trauma patients aged 15 years and above, the patients were divided into four groups according to their BMI (< 25, 25–29.9, 30–34.9, and ≥ 35 kg/m²), and injury severity was compared among the four groups [21]. The mean ISS showed significant intergroup differences; in particular, a

subgroup analysis demonstrated that the group with a BMI < 25 kg/m² had a significantly lower ISS than the other three groups. Consistent with our findings, trauma patients with a BMI ≥ 25 kg/m² had a higher ISS. However, the analysis of that study did not distinguish various mechanisms of injury, including motor vehicle accidents, falling from a height, and simple falls. Thus, there were difficulties in understanding how the mechanism of injury affects the impact of obesity on the pattern of injuries.

Another study compared the severity of injuries and outcomes according to obesity status in blunt trauma patients. Unlike the other study, the mean ISS (12.6 vs. 11.8), abdomen AIS, head

AIS, and mortality rate (6.8% vs. 3.5%) were not significantly different between nonobese and obese patients [22]. However, the specific mechanism of blunt trauma was also not distinguished in that study. Most importantly, only 815 out of 7,030 trauma patients were assessed for BMI and included in the study. Thus, the risk of bias was high. Similarly, another study on hospitalized patients injured in motorcycle accidents reported that there was no difference in injury severity according to obesity status (mean ISS, 9.7 vs. 9.3) [23].

In a previous study that analyzed the severity and pattern of injuries according to obesity status in patients who had fallen down, mortality and the AIS for various body parts were not significantly different between obese and normal-weight groups. By contrast, the ISS was significantly lower in obese patients than in normal-weight patients; however, the reason for the difference in ISS was not provided [24]. Taken together, these studies have reported various findings on the severity of injury according to obesity status in blunt trauma patients. However, there is a lack of studies evaluating the effects of obesity on the severity of pedestrian injuries. For this reason, our study makes a novel and meaningful contribution to the literature.

In a computational study of the injury patterns of overweight drivers involved in motor vehicle crashes using dummy modeling, a higher BMI was associated with an elevated risk of injury in the head, thorax, and lower extremities, excluding the abdomen [25]. According to that study, in obese persons, the adipose tissue accumulated in the abdomen provides a cushioning effect for protection. In other body parts, in contrast, adipose tissue has less prominent cushioning effects. Thus, the effect of momentum due to a higher BMI exceeds the cushioning effects of adipose tissue, causing an overall increase in the injury risk. This proposal seems to be applicable to understanding the results of our study, which showed that obesity might have an overall detrimental effect on the severity of injuries. In our study, as well as having a higher risk of critical injury, the obese group also had a higher risk of severe head injury than the nonobese group (86.2% vs. 67.4%; $P = 0.005$). Moreover, although the difference was not statistically significant, the rate of severe abdominal injuries was lower in obese patients (51.2%) than in nonobese patients (63.3%), suggesting that obesity may have protective effects against abdominal trauma, in accordance with the interpretation of the computational study discussed above. However, there were no meaningful differences in other body parts (thorax, spine, upper extremity, and lower extremity). Several studies have also reported findings regarding the relationship between obesity and injuries to specific body parts; however, the results differ depend-

ing on the injury mechanism [16,26,27].

The OR for critical injury in men was 1.74 (95% CI, 1.10–2.74). Another study that evaluated the effects of age on injury severity in older patients who experienced pedestrian traffic accidents reported that male sex was associated with an ISS of more than 25 (OR, 1.23; 95% CI 1.11–1.36). This finding is consistent with our observations [28]. In a study that analyzed traffic accident data from the United States, the fatality rate per 100 collisions was approximately 1.98 times higher in men than in women (8.14 vs. 4.12) [29]. However, these two studies did not explain why men were more likely to experience severe injuries and mortality in pedestrian traffic accidents than women.

This study has several limitations. First, this study was conducted retrospectively using data collected from a single medical institution. Thus, the characteristics of patients who experienced traffic accidents as pedestrians cannot be generalized. Second, only those who were hospitalized or transferred were included in our study; therefore, patients who were discharged based on their emergency room test results were not included. The reason for this is that only hospitalized patients who presented to the emergency room or trauma resuscitation room of participating hospitals and were assigned S- and T-codes were included in the KTDB, excluding those who were discharged home. However, clinical injury severity is expected to be low in patients who do not require hospitalization, and it is likely that the exclusion of those patients did not significantly affect the findings of our study. Third, patients were assigned to nonobese and obese groups based on a BMI of 25 kg/m^2 . For Asians, a BMI of less than 18.5 kg/m^2 is considered underweight. Only 7% of the participants in this study were underweight, making it difficult to assess the effects of obesity on the severity of injury in the full range of BMI categories. These limitations were also observed in the previous studies that have been described above and should be addressed in future research once sufficient data are collected.

In conclusion, obesity is a significant risk factor for severe injuries in pedestrian traffic accidents. Further studies are needed to analyze the effects of BMI on the pattern and severity of injuries in patients with more diverse mechanisms of injury using large-scale data.

NOTES

Ethical statements

The study was approved by the Institutional Review Board of Gachon University Gil Medical Center with a waiver for the need for informed consent (No. GAIRB2021-228).

Conflicts of interest

The authors have no conflicts of interest to declare.

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Author contributions

Conceptualization: all authors; Data curation: all authors; Formal analysis: all authors; Methodology: all authors; Project administration: PO, JC; Visualization: PO, JC; Writing—original draft: PO, JC; Writing—review & editing: all authors.

All authors read and approved the final manuscript.

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