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Trauma injury in adult underweight patients

A cross-sectional study based on the trauma registry system of a level I trauma center

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Abstract

The aim of this study was to investigate and compare the injury characteristics, severity, and outcome between underweight and normal-weight patients hospitalized for the treatment of all kinds of trauma injury.

This study was based on a level I trauma center Taiwan.

The detailed data of 640 underweight adult trauma patients with a body mass index (BMI) of $<18.5\,kg/m^2$ and 6497 normal-weight adult patients ($25 > BMI \geq 18.5\,kg/m^2$) were retrieved from the Trauma Registry System between January 1, 2009, and December 31, 2014. Pearson's chi-square test, Fisher's exact test, and independent Student's *t*-test were performed to compare the differences. Propensity score matching with logistic regression was used to evaluate the effect of underweight on mortality.

Underweight patients presented a different bodily injury pattern and a significantly higher rate of admittance to the intensive care unit (ICU) than did normal-weight patients; however, no significant differences in the Glasgow Coma Scale (GCS) score, injury severity score (ISS), in-hospital mortality, and hospital length of stay were found between the two groups. However, further analysis of the patients stratified by two major injury mechanisms (motorcycle accident and fall injury) revealed that underweight patients had significantly lower GCS scores (13.8 ± 3.0 vs 14.5 ± 2.0, $P=0.020$), but higher ISS (10.1 ± 6.9 vs 8.4 ± 5.9, $P=0.005$), in-hospital mortality (odds ratio, 4.4; 95% confidence interval, 1.69–11.35; $P=0.006$), and ICU admittance rate (24.1% vs 14.3%, $P=0.007$) than normal-weight patients in the fall accident group, but not in the motorcycle accident group. However, after propensity score matching, logistic regression analysis of well-matched pairs of patients with either all trauma, motorcycle accident, or fall injury did not show a significant influence of underweight on mortality.

Exploratory data analysis revealed that underweight patients presented a different bodily injury pattern from that of normal-weight patients, specifically a higher incidence of pneumothorax in those with penetrating injuries and of femoral fracture in those with struck on/against injuries; however, the injury severity and outcome of underweight patients varied depending on the injury mechanism.

Abbreviations: AIS = abbreviated injury scale, BAC = blood alcohol concentration, BMI = body mass index, CAD = coronary artery disease, CHF = congestive heart failure, CI = confidence interval, CVA = cerebral vascular accident, DM = diabetes mellitus, ED = emergency department, ESRD = end-stage renal disease, GCS = Glasgow Coma Scale, HTN = hypertension, ICU = intensive care unit, ISS = injury severity score, LOS = length of stay, MV = motor vehicle, NISS = new injury severity score, OR = odds ratio, TRISS = trauma injury severity score.

Keywords: injury severity score, intensive care unit, length of stay, mortality, normal-weight, trauma, underweight

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1. Introduction

Most of the studies on trauma outcomes and body weight have focused on obese patients, and the underweight population is almost always neglected.[1] The odds ratio (OR) for sustaining an injury with an injury severity score (ISS) of ≥9 had been reported to be 1.008 (95 confidence interval [95% CI], 1.004–1.011) for each kilogram increase in body weight.[2] Although minor differences in the injury mechanisms and patterns had been reported between obese and underweight patients,[3] a U-shaped correlation between the body mass index (BMI) and in-hospital mortality was described,[4,5] demonstrating a higher increase in mortality in underweight patients than in obese patients.[5,6] In a study of 5766 adult trauma patients with an ISS of ≥16, obesity was associated with multiorgan failure and sepsis mortality in the long-term follow-up, whereas underweight was associated with an increased mortality rate in the first 24 hours.[3] In addition, a lower 90-day survival was found in underweight patients than in normal-weight patients in a retrospective study of 461 patients >45 years.[7] Notably, there were relatively few researches performed on the underweight trauma patients than those studies performed on the obese population. According to The Trauma Registry of the German society for Trauma Surgery, the suicide rate in underweight patients (13.0%) was approximately twice as high as those who had normal weight (6.5%) or overweight (6.1%).[3] In addition, head injury was less frequent in the underweight and obese BMI groups, while abdominal injury rates were highest in the underweight subgroup.[3] Underweight athletes sustained a larger proportion of fractures (injury proportion ratio = 1.45, 95% CI: 1.10–1.92) than normal weight athletes.[8] Among the patients who sustained severe blunt trauma with hemorrhagic shock, those who were underweight had higher lactate levels, were four times more likely to die, and were two times more likely to undergo a laparotomy than patients with normal weight.[9] However, in a study of traumatic brain injuries caused by low-level falls, the patients in all BMI groups were of similar injury severity and neurological status.[10]

Notably, being underweight is extensively promoted in the media as being fashionable, healthy, and highly desirable. Gaining a greater understanding of the epidemiology of trauma in underweight patients is vital in integrating the knowledge of trauma care into the local trauma system that would manage these underweight patients. In Taiwan, around ~11% of grade six school children were underweight in a study across 2400 elementary schools[11] and 6.4% of older adults (aged ≥60) were underweight in a nationally representative survey.[12] In Taiwan, the mechanism of trauma injury is different from that in Western countries, with motorcycle accidents and fall injuries comprising most of the trauma injuries that require hospital admission.[13–15] Because the mechanism of trauma injury is distinct, this study was designed to investigate the injury characteristic, pattern, and severity, as well as the mortality of underweight patients treated for all trauma injuries in southern Taiwan, by using the data from a population-based trauma registry. The primary outcome was in-hospital mortality, and the secondary outcomes were length of stay (LOS) in the hospital and intensive care unit (ICU) and the injury severity based on the different scoring systems including Glasgow Coma Scale (GCS), abbreviated injury scale (AIS), and injury severity score (ISS).

2. Methods

2.1. Ethics statement

This study was preapproved by the institutional review board (IRB) of Chang Gung Memorial Hospital with approval numbers 104-5390B, 104-5392B, and 104-5393B. An informed consent was waived according to IRB regulations.

2.2. Study design

This retrospective study was designed to review all the data added to the Trauma Registry System of a 2400-bed facility and level I regional trauma center that provides care to trauma patients primarily from south Taiwan. Cases were selected according to the following inclusion criteria: (i) adult patients aged 20–65 years and with hospitalization for the treatment of all kinds of trauma injury and (ii) underweight patients with a BMI of $<18.5\,kg/m^2$ and normal-weight patients with a BMI of <25 but $\geq 18.5\,kg/m^2$ according to the definition of the World Health Organization.[6,16] Patients with incomplete registered data or invalidated data were excluded. To compare the injury characteristic, injury severity, and outcome of underweight patients from those of normal-weight patients, we reviewed all 20,106 hospitalized and registered patients added to the Trauma Registry System from January 1, 2009, to December 31, 2014. Of the total of 20,106 patients, 11,570 adults with complete registered data were selected for further analysis. Among them, motorcycle accident (n = 5823) was the major reason for admission, followed by falls (n = 2275) and struck on/against injuries (n = 1563). Among these 11,570 adult patients, 640 (5.5%) and 6497 (56.2%) were underweight and of normal weight, respectively. Of the patients with motorcycle accidents, 356 (6.1%) and 3272 (56.2%) were underweight and of normal weight, respectively. Detailed patient information was retrieved, including age, sex, vital signs on admission, injury mechanism, status of helmet wearing in motorcycle riders, blood alcohol concentration (BAC), the first GCS score at the emergency department (ED), AIS severity score of each body region, ISS, new ISS (NISS), trauma ISS (TRISS), LOS in the hospital, LOS in the ICU, in-hospital mortality, and rates of associated complications. Clinical assessment of post-traumatic impaired consciousness is evaluated by GCS which is calculated by the addition of three components including eye (E), verbal (V), and motor (M) response to external stimuli.[17] The calculated points would give a patient GCS score between 3 (indicating deep unconsciousness) and 15 (indicating clear). AIS is a coding system to score every injury in an anatomical region according to 6 severity points which range as follow: minor (1 point), mild (2 point), serious (3 point), severe (4 point), critical (5 point), and mortal (6 point).[18] The ISS is the sum of the square of AIS score of three most severe injuries, with only consideration of 1 injury per body region.[19] The NISS is a modification of the ISS to calculate the sum of the square of AIS score of 3 most severe injuries, but regardless of body region.[20] The TRISS is used to estimate the probability of survival by calculating the patient's age, type of injury, Revised Trauma Score (a physiologic scoring system made up of 3 categories: GCS, systolic blood pressure, and respiratory rate), and ISS.[21] Preexisting comorbidities and chronic diseases, including diabetes mellitus, hypertension (HTN), coronary artery diseases, congestive heart failure, cerebrovascular accident, and end-stage renal disease, were identified. The fall heights (<1 meter (m), 1–6 m, and >6 m) of the patients who had sustained fall injuries were identified; however, those who fell during an attempted suicide or who had nonvalidated BMI values or incomplete data were excluded. A BAC level of 50 mg/dL at the time of arrival to the emergency department was defined as the cutoff value for alcohol intoxication. The SPSS v.20 statistical software (IBM, Armonk, NY) was used to analyze the collected data for the performance of Pearson's chi-square test, Fisher's exact test, or independent

Student's *t*-test, as applicable. The ORs and 95% CIs of the associated conditions and injuries of underweight and normal-weight patients were calculated. Adjusted ORs with 95% CIs for mortality controlled by the confounder ISS were also calculated. In the assessment of mortality, propensity scores were calculated using a logistic regression model with correction of the following covariates: gender; age; DM; HTN; CAD; alcohol intoxication (BAC > 50 mg/dL); GCS; injuries to the head/neck, thorax, or extremities based on AIS; and ISS to minimize confounding effects of nonrandomized assignment. The NCSS software (NCSS 10, NCSS Statistical software, Kaysville, UT) was used to create a 1:1 matched study group with the Greedy method, then a binary logistic regression was used to evaluate the interventional factor of underweight on mortality. All results for the continuous variables are presented as the mean ± standard deviation. A *P*-value of <0.05 was considered statistically significant.

3. Results

3.1. Demographics and injury characteristic of underweight patients

Of the patients with fall accidents, 108 (4.7%) patients were underweight and 1283 (56.4%) were normal weight (Table 1). Statistically more underweight and less normal-weight patients were females. In addition, underweight patients were significantly younger than normal-weight patients. Underweight patients were significantly less likely to have had preexisting HTN (OR, 0.5; 95% CI, 0.35–0.69; $P<0.001$) than normal-weight patients. Among the underweight patients, the trauma mechanism was similar to that of the all trauma patients, with motorcycle accidents being the major reason for admission (51.4%), followed by falls (16.9%) and struck on/against injuries (11.7%). Moreover, motorcycle accidents occurred more frequently in younger patients and fall accidents in older patients (Fig. 1). A positive blood alcohol concentration was significantly less frequent among underweight patients than among normal-weight patients (5.8% vs 8.7%, $P=0.013$).

3.2. Injury severity and outcome of underweight patients

Regarding the GCS score or the distribution of patients at different levels of consciousness (GCS ≤8, 9–12, or ≥13), there were no significant difference between underweight and normal-weight patients (Table 1). The major GCS scores of patients in both groups were ≥13. Concerning the AIS scores, underweight patients had a significantly higher rate of head/neck injury than normal-weight patients, whereas normal-weight patients had a significantly higher rate of extremity injury. No significant differences were found between underweight and normal-weight patients with respect to ISS (8.7 ± 7.9 vs 8.2 ± 7.2, $P=0.084$) regardless of the injury severity subgroup, NISS, TRISS, in-hospital mortality, in-hospital mortality controlled by the confounder ISS, and hospital LOS. After propensity score matching, 79 well-balanced pairs of patients were used for comparison of mortality (Supplementary Table 1, http://links.lww.com/MD/B585). In these propensity score-matched patients selected with no significant difference in gender; age; comorbidity; alcohol intoxication; GCS; injury to head/neck, thorax, or extremities based on AIS; and ISS, logistic regression analysis did not show that underweight significantly influenced mortality (OR: 1.3; 95% CI: 0.48–3.45; $P=0.617$). Furthermore, underweight patients had significantly higher rate of ICU admittance than normal-weight patients (20.6% vs 17.3%, $P=0.033$), with the difference noted mainly in patients with an ISS of <16. However, the ICU LOS was significantly shorter for underweight patients than for normal-weight patients (7.0 vs 8.9 days, $P=0.019$).

3.3. Physiological response and procedures performed in the ED

In the ED, underweight patients were more likely to present with worse measurements of systolic blood pressure (SBP) <90 mm Hg (OR, 1.7; 95% CI, 1.07–2.63; $P=0.022$), heart rate (HR) >100 beats/min (OR, 1.3; 95% CI, 1.04–1.54; $P=0.018$), and respiratory rate (RR) <10 or >29 (OR, 2.6; 95% CI, 1.11–5.87; $P=0.033$) than normal-weight patients (Table 2). There were no significant differences between groups with respect to the performed procedures, including cardiopulmonary resuscitation, intubation, chest tube insertion, or blood transfusion.

3.4. Associated site of injuries of underweight patients

Underweight patients were more likely to have sustained a pneumothorax (OR, 1.6; 95% CI, 1.00–2.61; $P=0.047$) and femoral fracture (OR, 1.3; 95% CI, 1.01–1.70; $P=0.045$) than normal-weight patients (Table 3). More underweight patients than normal-weight patients had sustained pneumothorax in a penetrating injury (10.0% vs 0.0%, $P=0.018$) (Fig. 2) and femoral fracture in the injury mechanism of having struck on/against an object (7.1% vs 2.3%, respectively, $P=0.040$) (Fig. 3).

3.5. Injured underweight motorcycle riders

Further analysis was performed with a focus on the first two major trauma mechanisms (motorcycle and fall accidents) that resulted in an admission of underweight patients. The underweight motorcycle riders were significantly younger than the normal-weight patients (33.1 ± 13.8 and 40.7 ± 14.4 years, respectively; $P<0.001$) (Table 4). Statistically significantly fewer men and more women were found among the underweight motorcycle riders. The difference in helmet wearing between underweight and normal-weight motorcycle riders was not statistically significant. However, a positive BAC was less frequent among underweight than among normal-weight motorcycle riders (5.3% vs 11.4%, $P<0.001$). No significant differences in the GCS scores, distribution of the proportion of patients at different levels of consciousness (GCS ≤8, 9–12, or ≥13), and AIS of body regions were found between underweight and normal-weight motorcycle riders. Also, no significant differences were found between underweight and normal-weight motorcycle riders for ISS regardless of the subtype of injury severity, in-hospital mortality, in-hospital mortality controlled by the confounder ISS, in-hospital mortality of 35 pairs of patients after propensity score matching (Supplementary Table 2, http://links.lww.com/MD/B585), in-hospital LOS, proportion of patients admitted into the ICU, and LOS in the ICU. Concerning the injuries associated with motorcycle accidents, only a significantly higher odds of underweight motorcycle riders had sustained sacral vertebral fractures (OR, 3.7; 95% CI, 1.44–9.66; $P=0.013$) than normal-weight patients. In contrast, a significantly lower odds of underweight motorcycle riders had sustained rib fractures (OR, 0.6; 95% CI, 0.36–0.86; $P=0.008$).

3.6. Injured underweight patients with fall accidents

In contrast to the findings in the injured underweight motorcycle riders, there was no statistically significant difference in sex and age between the underweight and normal-weight patients with

Table 1

Demographics and injury characteristics of underweight and normal-weight adult patients with all trauma injuries.

Variables	Underweight BMI <18.5, n=640	Normal 25> BMI ≥18.5, n=6497	Odds ratio (95% CI)	P
Gender				
Male	303 (47.3)	3892 (59.9)	0.6 (0.51–0.71)	<0.001
Female	337 (52.7)	2605 (40.1)	1.7 (1.41–1.96)	<0.001
Age, y	36.8±14.4	43.0±13.8	–	<0.001
20–29	285 (44.5)	1521 (23.4)	2.6 (2.22–3.10)	<0.001
30–39	98 (15.3)	1143 (17.6)	0.8 (0.68–1.06)	0.146
40–49	96 (15.0)	1285 (19.8)	0.7 (0.57–0.90)	0.004
50–59	108 (16.9)	1646 (25.3)	0.6 (0.48–0.74)	<0.001
60–65	53 (8.3)	902 (13.9)	0.6 (0.42–0.75)	<0.001
Comorbidity				
DM	34 (5.3)	456 (7.0)	0.7 (0.52–1.06)	0.103
HTN	39 (6.1)	755 (11.6)	0.5 (0.35–0.69)	<0.001
CAD	3 (0.5)	62 (1.0)	0.5 (0.15–1.56)	0.217
CHF	3 (0.5)	14 (0.2)	2.2 (0.63–7.61)	0.191
CVA	5 (0.8)	88 (1.4)	0.6 (0.23–1.42)	0.222
ESRD	2 (0.3)	5 (0.1)	4.1 (0.79–21.02)	0.125
Mechanism, n (%)				
MV driver	15 (2.3)	122 (1.9)	1.3 (0.73–2.16)	0.412
MV passenger	6 (0.9)	58 (0.9)	1.1 (0.45–2.45)	0.909
Motorcycle driver	329 (51.4)	3110 (47.9)	1.2 (0.98–1.36)	0.087
Motorcycle pillion	27 (4.2)	162 (2.5)	1.7 (1.14–2.61)	0.009
Bicycle	17 (2.7)	195 (3.0)	0.9 (0.53–1.46)	0.624
Pedestrian	11 (1.7)	106 (1.6)	1.1 (0.56–1.97)	0.868
Fall	108 (16.9)	1302 (20.0)	0.8 (0.65–1.01)	0.055
Penetrating injury	34 (5.3)	396 (6.1)	0.9 (0.60–1.24)	0.427
Burn	18 (2.8)	197 (3.0)	0.9 (0.57–1.51)	0.756
Struck on/against	75 (11.7)	849 (13.1)	0.9 (0.69–1.14)	0.332
Alcohol >50 mg/dL, n (%)	37 (5.8)	562 (8.7)	0.6 (0.46–0.91)	0.013
GCS	14.2±2.5	14.3±2.2	–	0.169
≤8	36 (5.6)	301 (4.6)	1.2 (0.86–1.75)	0.259
9–12	26 (4.1)	227 (3.5)	1.2 (0.77–1.77)	0.458
≥13	578 (90.3)	5969 (91.9)	0.8 (0.63–1.09)	0.171
AIS ≥1, n (%)				
Head/Neck	188 (29.4)	1612 (24.8)	1.3 (1.05–1.51)	0.011
Face	139 (21.7)	1265 (19.5)	1.1 (0.94–1.40)	0.172
Thorax	74 (11.6)	772 (11.9)	1.0 (0.75–1.25)	0.811
Abdomen	40 (6.3)	431 (6.6)	0.9 (0.67–1.31)	0.709
Extremity	441 (68.9)	4730 (72.8)	0.8 (0.69–0.99)	0.035
ISS	8.7±7.9	8.2±7.2	–	0.084
<16	547 (85.5)	5555 (85.5)	1.0 (0.79–1.26)	0.982
16–24	59 (9.2)	653 (10.1)	0.9 (0.69–1.20)	0.503
≥25	34 (5.3)	289 (4.4)	1.2 (0.84–1.74)	0.316
NISS	10.1±9.7	9.5±8.7	–	0.071
TRISS	0.967±0.115	0.968±0.101	–	0.819
Mortality, n (%)	13 (2.0)	83 (1.3)	1.6 (0.89–2.89)	0.114
Controlled by ISS	–	–	1.4 (0.71–2.61)	0.350
LOS, d	9.5±10.0	9.3±9.9	–	0.644
Stay in ICU				
Patients, n (%)	132 (20.6)	1122 (17.3)	1.25 (1.02–1.52)	0.033
<16	58 (9.1)	436 (6.7)	1.4 (1.04–1.85)	0.025
16–24	43 (6.7)	432 (6.6)	1.0 (0.73–1.40)	0.946
≥25	31 (4.8)	254 (3.9)	1.3 (0.85–1.83)	0.249
LOS in ICU, d	7.0±8.7	8.9±11.4	–	0.019

AIS = abbreviated injury scale, BMI = body mass index, CAD = coronary artery disease, CHF = congestive heart failure, CI = confidence interval, CVA = cerebral vascular accident, DM = diabetes mellitus, ESRD = end-stage renal disease, GCS = Glasgow Coma Scale, HTN = hypertension, ICU = intensive care unit, ISS = injury severity score, LOS = length of stay, MV = motor vehicle, NISS = new injury severity score, TRISS = trauma injury severity score.

fall accidents (Table 5). Most of the underweight and normal-weight patients fell from a height of <1 m. These results indicated that most of the patients were injured in a ground-level fall during walking or in their movement; however, when stratified the patients in groups by fall height (<1 m, 1–6 m, and >6 m), there were more underweight patients fell from a height of <1 m than did normal-weight patients, and there were more normal-weight patients fell from a height of 1–6 m than did underweight patients. No statistically significant difference in having had a positive BAC was found between the underweight and normal-weight patients with fall accidents. In the group with fall accidents, underweight patients had significantly lower GCS scores than normal-weight patients (13.8±3.0 vs 14.5±2.0, $P=0.020$). In addition, more underweight patients had a GCS of ≤8

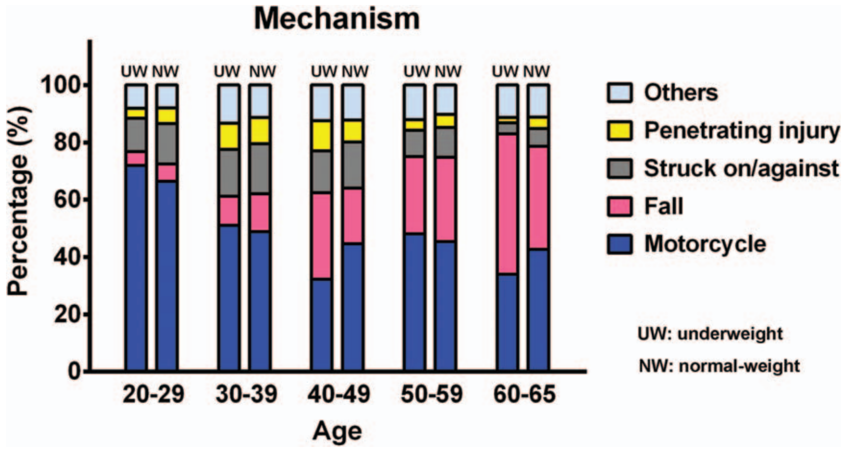

Figure 1. Distribution of age and mechanism of trauma of underweight and normal-weight adult trauma patients.

than normal-weight patients (8.3% vs 3.7%, respectively, $P=0.037$). On the contrary, fewer patients had a GCS of ≥13 than normal-weight patients (85.2% vs 93.3%, respectively, $P=0.002$). No significant differences in trauma regions between underweight and normal-weight patients with fall accidents were found according to the analysis of AIS scores. A significant difference in ISS (10.1±6.9 vs 8.4±5.9, $P=0.005$) was found between underweight and normal-weight patients with fall accidents. When stratified the injured patients into three groups (ISS of <16, 16–24, or ≥25) by injury severity, more underweight had an ISS of ≥25 (9.3% vs 3.9%, $P=0.021$) than normal-weight patients. Moreover, the underweight patients with fall accidents had a significantly higher ISS than that of underweight motorcycle riders (10.1±6.9 vs 8.9±7.1, $P<0.001$). Furthermore, in fall accidents, the underweight patients had a significantly higher in-hospital mortality than that of normal-weight patients (5.6% vs 1.3%, $P=0.006$). When controlled by the confounder ISS, the underweight patients still had a 2.9-fold higher in-hospital mortality than normal-weight patients with fall accidents ($P=0.047$). However, after propensity score matching, logistic regression of 15 well-matched pairs did not show a significant influence of obesity on mortality (Supplementary Table 3, http://links.lww.com/MD/B585), indicating some factors other than ISS may be attributed to the higher mortality of the underweight patients with fall. Notably, significantly more fatalities were found for underweight patients than normal-weight patients who sustained a fall from <1 m height (4.6% vs 0.9%, $P=0.007$). In addition, more underweight patients were admitted to the ICU (24.1% vs 14.3%, $P=0.007$) than normal-weight patients, with the difference noted in patients with an ISS of <16 and ≥25. However, the LOS in the ICU was shorter for underweight patients than for normal-weight patients (5.6 vs 8.6 days, $P=0.033$). In addition, concerning the injuries associated with fall accidents, there were no significant differences between underweight and normal-weight patients in those with fall accidents.

4. Discussion

This study analyzed the demographics and injury characteristics observed in a population of underweight adult patients against those of normal-weight patients hospitalized at a level I trauma center. In the analysis of patients admitted by all trauma injuries, underweight patients presented a different bodily injury pattern and a significantly higher rate of admittance to the ICU than normal-weight patients; however, no significant difference in the GCS score, ISS, in-hospital mortality, and hospital LOS were found between these two groups of patients. However, further analysis of the patients stratified by injury mechanism (motorcycle accident and fall injury) revealed different results. In the group with motorcycle accidents, no significant differences in GCS scores, ISS, in-hospital mortality, proportion of patients admitted into the ICU, and LOS in the ICU were found between underweight and normal-weight motorcycle riders. In contrast, in the group with fall accidents, underweight patients had significantly lower GCS scores,

Table 2

Physiological response and procedures performed on arrival at the emergency department.

Variables	Underweight BMI <18.5, n=640	Normal 25> BMI ≥18.5, n=6497	Odds ratio (95% CI)	P
Physiology at ED, n (%)				
GCS <13	62 (9.7)	528 (8.1)	1.2 (0.92–1.60)	0.171
Systolic blood pressure <90 mm Hg	23 (3.6)	141 (2.2)	1.7 (1.07–2.63)	0.022
Heart rate >100 beats/min	142 (22.2)	1193 (18.4)	1.3 (1.04–1.54)	0.018
Respiratory rate <10 or >29 times/min	7 (1.1)	28 (0.4)	2.6 (1.11–5.87)	0.033
Procedures at ED, n (%)				
Cardiopulmonary resuscitation	2 (0.3)	11 (0.2)	1.8 (0.41–8.36)	0.328
Intubation	19 (3.0)	157 (2.4)	1.2 (0.76–2.00)	0.390
Chest tube insertion	14 (2.2)	95 (1.5)	1.5 (0.86–2.66)	0.153
Blood transfusion	22 (3.4)	161 (2.5)	1.4 (0.89–2.20)	0.143

BMI = body mass index, CI = confidence interval, ED = emergency department, GCS = Glasgow Coma Scale.

Table 3

Associated sites of injury of underweight and normal-weight patients with all trauma injuries.

Variables	Underweight BMI <18.5, n=640	Normal 25> BMI ≥18.5, n=6497	Odds ratio (95% CI)	*P*
Head trauma, n (%)				
Neurologic deficit	5 (0.8)	60 (0.9)	0.8 (0.34–2.11)	0.718
Cranial fracture	44 (6.9)	398 (6.1)	1.1 (0.82–1.56)	0.453
EDH	25 (3.9)	261 (4.0)	1.0 (0.64–1.48)	0.891
SDH	52 (8.1)	528 (8.1)	1.0 (0.74–1.35)	0.999
SAH	57 (8.9)	535 (8.2)	1.1 (0.82–1.45)	0.557
ICH	10 (1.6)	130 (2.0)	0.8 (0.41–1.49)	0.445
Cerebral contusion	31 (4.8)	315 (4.8)	1.0 (0.68–1.46)	0.996
Cervical vertebral fracture	8 (1.3)	53 (0.8)	1.5 (0.73–3.25)	0.255
Maxillofacial trauma, n (%)				
Orbital fracture	14 (2.2)	146 (2.2)	1.0 (0.56–1.69)	0.922
Nasal fracture	7 (1.1)	83 (1.3)	0.9 (0.39–1.86)	0.691
Maxillary fracture	45 (7.0)	474 (7.3)	1.0 (0.70–1.32)	0.806
Mandibular fracture	24 (3.8)	185 (2.8)	1.3 (0.86–2.05)	0.196
Thoracic trauma, n (%)				
Rib fracture	43 (6.7)	549 (8.5)	0.8 (0.57–1.08)	0.130
Sternal fracture	0 (0.0)	13 (0.2)	–	0.622
Hemothorax	5 (0.8)	95 (1.5)	0.5 (0.22–1.31)	0.162
Pneumothorax	20 (3.1)	127 (2.0)	1.6 (1.00–2.61)	0.047
Hemopneumothorax	8 (1.3)	90 (1.4)	0.9 (0.44–1.87)	0.779
Lung contusion	10 (1.6)	64 (1.0)	1.6 (0.82–3.12)	0.169
Thoracic vertebral fracture	6 (0.9)	60 (0.9)	1.0 (0.44–2.36)	0.972
Abdominal trauma, n (%)				
Intra-abdominal injury	9 (1.4)	107 (1.6)	0.9 (0.43–1.69)	0.646
Hepatic injury	17 (2.7)	134 (2.1)	1.3 (0.78–2.16)	0.319
Splenic injury	3 (0.5)	66 (1.0)	0.5 (0.14–1.46)	0.177
Retroperitoneal injury	2 (0.3)	11 (0.2)	1.8 (0.41–8.36)	0.328
Renal injury	4 (0.6)	33 (0.5)	1.2 (0.44–3.49)	0.570
Urinary bladder injury	0 (0.0)	0 (0.0)	–	–
Lumbar vertebral fracture	10 (1.6)	122 (1.9)	0.8 (0.43–1.59)	0.572
Sacral vertebral fracture	8 (1.3)	40 (0.6)	2.0 (0.95–4.38)	0.072
Extremity trauma, n (%)				
Scapular fracture	7 (1.1)	119 (1.8)	0.6 (0.28–1.28)	0.176
Clavicle fracture	54 (8.4)	620 (9.5)	0.9 (0.65–1.17)	0.362
Humeral fracture	24 (3.8)	269 (4.1)	0.9 (0.59–1.38)	0.635
Radial fracture	61 (9.5)	688 (10.6)	0.9 (0.68–1.17)	0.405
Ulnar fracture	35 (5.5)	330 (5.1)	1.1 (0.76–1.55)	0.670
Metacarpal fracture	20 (3.1)	182 (2.8)	1.1 (0.70–1.79)	0.638
Pelvic fracture	25 (3.9)	187 (2.9)	1.4 (0.90–2.10)	0.144
Femoral fracture	70 (10.9)	558 (8.6)	1.3 (1.01–1.70)	0.045
Patella fracture	12 (1.9)	188 (2.9)	0.6 (0.36–1.16)	0.136
Tibia fracture	50 (7.8)	487 (7.5)	1.0 (0.77–1.42)	0.772
Fibular fracture	27 (4.2)	245 (3.8)	1.1 (0.75–1.69)	0.572
Calcaneal fracture	27 (4.2)	335 (5.2)	0.8 (0.54–1.21)	0.302
Metatarsal fracture	20 (3.1)	236 (3.6)	0.9 (0.54–1.36)	0.510

BMI = body mass index, CI = confidence interval, EDH = epidural hematoma, ICH = intracerebral hematoma, SAH = subarachnoid hemorrhage, SDH = subdural hematoma.

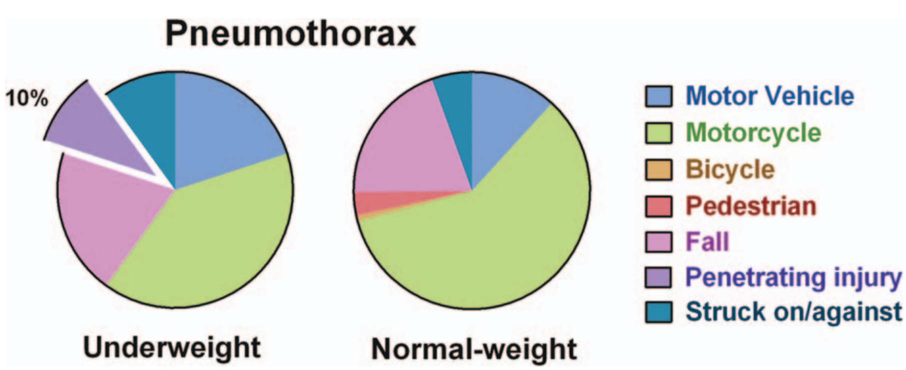

Figure 2. Proportion of underweight and normal-weight patients who had sustained pneumothorax from different trauma mechanisms.

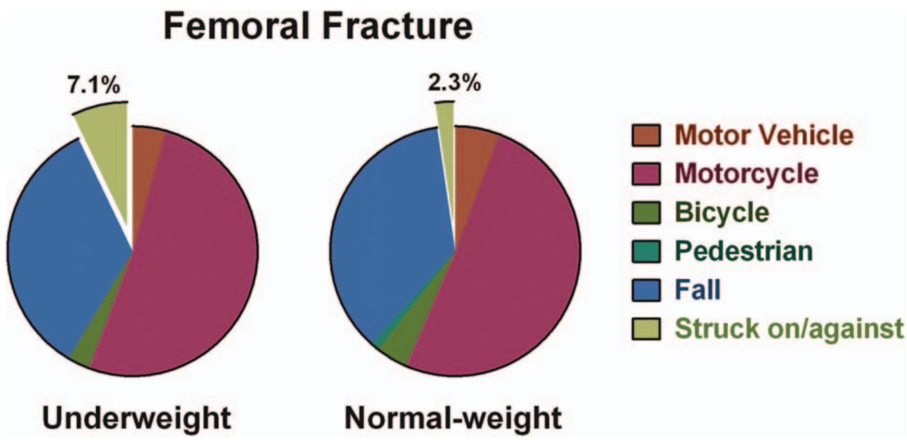

Figure 3. Proportion of underweight and normal-weight patients who had sustained femoral fracture from different trauma mechanisms.

higher ISS, and higher in-hospital mortality than normal-weight patients. Importantly, after propensity score matching, logistic regression analysis of well-matched pairs of patients with either all trauma, motorcycle accident or even fall injury did not show a significant influence of underweight on mortality, indicating some factors (e.g., older age or higher associated comorbidity in the patients with a fall) other than ISS may be attributed to the higher mortality of the underweight patients with fall.

In Taiwan, because motorcycle riding is generally forbidden on highways and most traffic accidents occur in relatively crowded streets, motorcycle injuries commonly occur at a relatively low velocity.[13] In this study, although most of the patients with fall accidents sustained a ground-level fall from <1 m height, the ISS of underweight patients with fall accidents was still significantly higher than that of underweight motorcycle riders (10.1 ± 6.9 vs 8.9 ± 7.1, P < 0.001). In consideration of the helmet-wearing

Table 4

Demographics and injury characteristics of underweight and normal-weight adult trauma patients with motorcycle accidents.

Variables	Underweight BMI <18.5, n=356	Normal 25> BMI ≥18.5, n=3272	Odds ratio (95% CI)	P
Gender				
Male	146 (41.0)	1754 (53.6)	0.6 (0.48–0.75)	<0.001
Female	210 (59.0)	1518 (46.4)	1.7 (1.33–2.08)	<0.001
Age, y	33.1 ± 13.8	40.7 ± 14.4	–	<0.001
Helmet use, n (%)				
Yes	320 (89.9)	2883 (88.1)	1.2 (0.84–1.72)	0.322
No	32 (9.0)	316 (9.7)	0.9 (0.63–1.35)	0.684
Unknown	4 (1.1)	73 (2.2)	0.5 (0.18–1.37)	0.169
Alcohol >50 mg/dL, n (%)	19 (5.3)	373 (11.4)	0.4 (0.27–0.70)	<0.001
GCS	14.3 ± 2.2	14.2 ± 2.5	–	0.128
≤8	16 (4.5)	194 (5.9)	0.7 (0.44–1.26)	0.271
9–12	13 (3.7)	148 (4.5)	0.8 (0.45–1.43)	0.448
≥13	327 (91.9)	2930 (89.5)	1.3 (0.89–1.96)	0.173
AIS ≥1, n (%)				
Head/Neck	122 (34.3)	1050 (32.1)	1.1 (0.88–1.39)	0.404
Face	101 (28.4)	917 (28.0)	1.0 (0.80–1.30)	0.891
Thorax	42 (11.8)	485 (14.8)	0.8 (0.55–1.08)	0.124
Abdomen	24 (6.7)	231 (7.1)	1.0 (0.62–1.47)	0.823
Extremity	257 (72.2)	2396 (73.2)	0.9 (0.74–1.21)	0.675
ISS	8.9 ± 7.1	9.3 ± 7.5	–	0.245
<16	308 (86.5)	2707 (82.7)	1.3 (0.98–1.84)	0.070
16–24	32 (9.0)	399 (12.2)	0.7 (0.49–1.04)	0.076
≥25	16 (4.5)	166 (5.1)	0.9 (0.52–1.49)	0.635
Mortality, n (%)	3 (0.8)	40 (1.2)	0.7 (0.21–2.23)	0.795
Controlled by ISS	–	–	0.8 (0.24–2.91)	0.782
LOS, d	9.0 ± 9.6	9.6 ± 10.0	–	0.337
Stay in ICU				
Patients, n (%)	70 (19.7)	607 (18.6)	1.1 (0.82–1.42)	0.609
<16	30 (8.4)	193 (5.9)	1.5 (0.98–2.19)	0.059
16–24	26 (7.3)	265 (8.1)	0.9 (0.59–1.36)	0.600
≥25	14 (3.9)	149 (4.6)	0.9 (0.49–1.50)	0.591
LOS in ICU, d	5.7 ± 5.0	6.9 ± 8.0	–	0.216

AIS = abbreviated injury scale, BMI = body mass index, CI = confidence interval, GCS = Glasgow Coma Scale, ICU = intensive care unit, ISS = injury severity score, LOS = length of stay.

Table 5

Demographics and injury characteristics of underweight and normal-weight adult trauma patients with fall accidents.

Variables	Underweight BMI <18.5, n=108	Normal 25> BMI ≥18.5, n=1283	Odds ratio (95% CI)	P
Gender				
Male	53 (49.1)	752 (58.6)	0.7 (0.46–1.01)	0.054
Female	55 (50.9)	531 (41.4)	1.5 (1.00–2.18)	0.054
Age, y	48.5±13.1	50.7±11.2	–	0.093
Height of fall, m				
<1	83 (76.9)	830 (64.7)	1.8 (1.14–2.88)	0.011
1–6	22 (20.4)	425 (33.1)	0.5 (0.32–0.84)	0.006
>6	3 (2.8)	28 (2.2)	1.3 (0.38–4.28)	0.729
Alcohol >50 mg/dL, n (%)	8 (7.4)	57 (4.4)	1.7 (0.80–3.71)	0.161
GCS	13.8±3.0	14.5±2.0	–	0.020
≤8	9 (8.3)	48 (3.7)	2.3 (1.12–4.91)	0.037
9–12	7 (6.5)	38 (3.0)	2.3 (0.99–5.21)	0.079
≥13	92 (85.2)	1197 (93.3)	0.4 (0.23–0.73)	0.002
AIS ≥1, n (%)				
Head/Neck	31 (28.7)	302 (23.5)	1.3 (0.85–2.02)	0.227
Face	13 (12.0)	123 (9.6)	1.3 (0.70–2.37)	0.410
Thorax	14 (13.0)	134 (10.4)	1.3 (0.71–2.30)	0.415
Abdomen	8 (7.4)	90 (7.0)	1.1 (0.50–2.25)	0.878
Extremity	71 (65.7)	953 (74.3)	0.7 (0.44–1.01)	0.053
ISS	10.1±6.9	8.4±5.9	–	0.005
<16	85 (78.7)	1089 (84.9)	0.7 (0.41–1.07)	0.089
16–24	13 (12.0)	144 (11.2)	1.1 (0.59–1.98)	0.798
≥25	10 (9.3)	50 (3.9)	2.5 (1.24–5.12)	0.021
Mortality, n (%)	6 (5.6)	17 (1.3)	4.4 (1.69–11.35)	0.006
Controlled by ISS	–	–	2.9 (1.02–8.19)	0.047
Height of fall, m				
<1	5 (4.6)	12 (0.9)	5.1 (1.78–14.88)	0.007
1–6	1 (0.9)	5 (0.4)	2.4 (0.28–20.63)	0.385
LOS, d	10.0±9.1	8.4±9.3	–	0.070
Stay in ICU				
Patients, n (%)	26 (24.1)	184 (14.3)	1.9 (1.19–3.02)	0.007
<16	9 (8.3)	48 (3.7)	2.3 (1.12–4.91)	0.037
16–24	8 (7.4)	91 (7.1)	1.0 (0.49–2.22)	0.903
≥25	9 (8.3)	45 (3.5)	2.5 (1.19–5.27)	0.032
LOS in ICU, d	5.6±5.0	8.2±9.3	–	0.033

AIS = abbreviated injury scale, BMI = body mass index, CI = confidence interval, CVA = cerebral vascular accident, DM = diabetes mellitus, GCS = Glasgow Coma Scale, ICU = intensive care unit, ISS = injury severity score, LOS = length of stay.

habit in most of the motorcycle riders but not in patients with fall injuries, and the existence of different presentations of GCS scores in patients with motorcycle and fall accidents, we suspected that the higher ISS and mortality in underweight patients with fall accidents may be attributed to head injuries; however, the absence of a difference in head and neck injuries based on AIS analysis and on the incidences of associated head trauma (Supplementary Tables 1 and 2, http://links.lww.com/MD/B585) does not support this hypothesis. Therefore, a further population-based analysis with direct test of helmet-wearing in underweight population is required to achieve more solid conclusion regarding the protective or harmful effects of helmet-wearing. Furthermore, it had been reported that the associated decreased caloric and functional reserve of underweight patients making them more vulnerable to a physiologic stress such as a hip fracture than the obese patients.[22] The reduced physiological reserve may be partly explained by the findings of this study that underweight patients were more likely to present with worse measurements of SBP <90 mm Hg, HR >100 beats/min, and respiratory rate <10 or ≥29 times/min than the normal-weight patients. However, more evidence is required to validate whether the reduced caloric and functional reserve of underweight patients affects the outcomes for normal-weight patients only in the condition with a higher ISS, such as in fall accidents but not in motorcycle accidents in this study.

In this study, a positive BAC was less frequently observed among underweight patients than in normal-weight patients with all trauma injuries or with motorcycle accidents. Unsurprisingly, prevalent high-risk behaviors such as excessive alcohol use, which may contribute to excess body weight and the co-occurrence of obesity, and any alcohol use were frequently encountered.[23] Furthermore, the real incidence of alcohol intoxication in underweight patients may be lower than that in normal-weight patients, in consideration the requirement of a higher amount of alcohol to reach the same level of blood alcohol concentration in a patient with a higher body fat mass;[24] however, this suggestion could not be verified in this study because of its retrospective design. In addition, in a study of 1976 patients with traumatic hemorrhagic shock, underweight patients received significantly higher volumes of blood transfusion than did normal-weight patients (4751±470 mL vs 3182±125 mL, $P<0.001$) within 12 hours of injury.[9] Although higher transfusion rates in underweight patients, because of their low functional reserves and a suspected higher impact of equivalent blood loss in trauma, are suspected, no statistically significant relationship between the packed red blood cell transfusion rates during resuscitation had been reported between underweight and normal-weight patients.[3] In this study, there were no significant differences between groups with respect to blood transfusion and other performed procedures such as cardiopulmonary resuscitation, intubation, and chest tube insertion.

Notably, in this study, more underweight patients had sustained a pneumothorax in a penetrating injury (0.0% vs 10.0%, $P=0.018$) than did normal-weight patients. It had been reported that underweight patients were more likely to have a thoracotomy/sternotomy/video-assisted thoracoscopic surgery (OR, 2.10; 95% CI, 1.14–3.85; $P<0.017$) than normal-weight patients.[9] In addition, in an evaluation of the depths to which acupuncture needles can be inserted safely in the chest acupuncture points, and the variations in safe depth according to sex, age, body weight, and BMI, an increase in the BMI was significantly correlated with the increase in safe depth.[25] The safe depth in the obesity group was 1.23–1.75 times deeper than that in the underweight group.[25] Reasonably, the higher incidence of pneumothorax may be related to the thin skin and soft tissue coverage of the chest of underweight patients. In this study, more underweight patients also had sustained a femoral fracture in struck on/against injuries (2.3% vs 7.1%, $P=0.040$) than did normal-weight patients. In a hospital-based cohort study of 1614 postmenopausal Japanese women followed for 6.7 years, the incidence rates of femoral neck and long-bone fractures in the underweight group were higher than those in the overweight and obese group by 2.15 (95% CI, 0.73–6.34) and 1.51 (95% CI, 0.82–2.77), respectively.[26] A positive correlation had been reported between bone mineral density and BMI;[27] however, as increased body fat also has a negative effect on attaining the peak bone mass and bone mineral content,[28] the effect of underweight on the peak bone mass and bone mineral content as well as the fracture incidence are less explored. Moreover, some authors proposed the presence of a "cushion effect" that protects overweight patients from immediate death during a motor vehicle crash.[29] Whether there is less "cushion effect" in underweight patients to protect them from sustaining a pneumothorax in a crash injury and a direct contusion force on the femur resulting in fracture is interesting and warrant further investigation. Notably, in a study of all elderly patients receiving urgent hip fracture repairs, those who were underweight had a significantly higher risk of developing myocardial infarction (OR, 1.44; 95% CI, 1.0–2.1; $P=0.05$) and arrhythmias (OR, 1.59; 95% CI, 1.0–2.4; $P=0.04$) than normal-BMI patients.[22] Therefore, it had been suggested that maintaining an optimal body weight can reduce the risk of chronic diseases and mortality in polytraumatic underweight patients.[3]

The limitations of this study include the use of a retrospective design with its inherent selection bias. The lack of data on the circumstances of the mechanisms of injury, in terms of the impact type and force, as well as the use of any other protective materials, also limit the interpretation of the analyzed data. Moreover, the Trauma Registry Database only registered those patients who hospitalized for treatment, but not included those injured persons who received treatment in clinics, those patients who died before hospital arrival or at accident scene, and therefore confers a bias in the analysis. Finally, this study is only descriptive in nature and therefore is unable to assess the effects of any particular treatment intervention. We could only rely on the assumption that the assessment and management were uniform between the underweight and normal-weight patients. The effect of underweight on the incidence of associated injuries and outcomes in trauma patients remains inconclusive without a matched cohort prospective study.

5. Conclusion

Exploratory data analysis revealed that underweight patients presented different injury characteristics and bodily injury patterns, specifically a higher incidence of pneumothorax from a penetrating injury and of femoral fracture from a struck on/against injury, and a significantly higher rate of admittance to the ICU than the analyzed normal-weight patients. However, compared with normal-weight patients, the presentation of injury severity (GCS scores and ISS) and outcome (mortality and proportion of patients admitted to the ICU) varied when these underweight patients were stratified by injury mechanism (motorcycle accident and fall injury).

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