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Sex-specific impacts of obesity on long-term prognosis of traumatic brain injury: a multicenter prospective study

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Abstract

Our investigation delves into the nuanced interplay between obesity and sex on the long-term outcomes of traumatic brain injury (TBI), a relationship that previous studies have hinted at but not thoroughly elucidated. Acknowledging the divergent recovery paths of males and females post-TBI, we aimed to elucidate whether obesity's prognostic impact on TBI prognosis is indeed sex-dependent. This study was a prospective multi-center cohort study conducted on adult TBI patients, with intracranial hemorrhage or diffuse axonal injury confirmed by radiological examination, admitted to five participating emergency departments (EDs) from December 2018 to March 2023. The study outcomes were 6-month disability and mortality. The primary exposure was obesity, defined as body mass index (BMI) over 25. Multi-level logistic regression analysis was performed to estimate the association between obesity and the study outcomes. We conducted a stratified analysis by sex to investigate whether the association between obesity and TBI outcomes differs between sex. Our multilevel logistic regression analysis, using the normal weight group as a reference, indicated that higher BMI categories over 25 did not significantly alter the risk of 6-month disability or mortality when compared to the normal weight group. Our study revealed a higher one-month disability rate in female TBI patients with a BMI over 30 compared to those with a normal BMI, highlighting the need for gender-specific approaches in managing and rehabilitating TBI outcomes.

Keywords

Sex; Obesity; TBI

1. Introduction

Traumatic brain injury (TBI) is a substantial public burden, with an estimated 69 million individuals worldwide sustaining such injuries annually [1]. In the United States alone, TBIs account for approximately 2.87 million emergency department visits, hospitalizations and deaths each year, according to the Centers for Disease Control and Prevention (CDC) [2]. The pathogenesis of TBI typically involves a sudden and violent impact to the head, leading to a cascade of cellular and molecular events that can cause brain damage, ranging from mild concussions to severe brain injuries [3]. This not only challenges modern healthcare with a diverse range of acute presentations but also necessitates evolving strategies for long-term management, reflecting the complexity and heterogeneity of TBI cases [4]. The impact is not solely on immediate medical care; long-term disabilities from TBI affect approximately 5.3 million Americans, necessitating ongoing assistance at an estimated annual cost of $76.5 billion, which includes direct and indirect medical expenses [5, 6]. Chronic disabilities resulting from TBI can manifest in a range of impairments, from cognitive and motor dysfunction to personality changes, severely diminishing individuals' quality of life and ability to integrate into society and the workforce [7, 8]. This complex array of long-term consequences demands significant and sustained investments in healthcare resources, rehabilitation and support systems, illustrating the critical need for effective management strategies to mitigate the profound societal and economic impacts of TBI [9, 10]. Identifying predictive factors for TBI outcomes is critical for optimizing resource allocation and enhancing prognostic efforts [11, 12]. Understanding the variables that influence recovery trajectories enables healthcare providers to tailor interventions more effectively and to allocate resources where they are most needed [13, 14].

Various studies have reported on the relationship between obesity and the incidence, severity and outcomes of traumatic brain injury (TBI) [15–17]. According to recent meta-analyses, obesity appears to be associated with a reduced

incidence of TBI yet is linked to increased severity of the injury. Moreover, there is no conclusive evidence that obesity is related to long-term functional outcomes or mortality following TBI [17, 18].

While it's recognized that sex can significantly influence TBI outcomes—with male and female showing different recovery trajectories—the interaction between obesity and sex in the context of TBI remains poorly explored [19, 20]. So, we hypothesized that the impact of obesity on long-term prognosis following TBI may differ according to sex. Our study aimed to investigated that the influence of obesity on the long-term prognosis of traumatic brain injury (TBI) and to perform an interaction analysis to determine if this association varies according to sex.

2. Methods

2.1 Study design, setting and data sources

This research was carried out as a multicenter prospective cohort investigation at five academic hospitals in Korea, utilizing the Pan-Asian Trauma Outcome Study for Traumatic Brain Injury (PATOS-TBI) database (https://clinicaltrials.gov/, ID: NCT04718935). The PATOS-TBI project aims to identify nutritional and metabolic markers predictive of TBI outcomes. The participants in this study were adult patients with TBI, including those with diffuse axial injuries and intracranial hemorrhages, who were admitted to the emergency departments (EDs) of the collaborating hospitals *via* emergency medical services (EMS) within 72 hours of injury. The inclusion criteria were a diagnosis of intracranial injury confirmed by computed tomography (CT) or magnetic resonance imaging (MRI) scans conducted in the ED. In cases of patient unconsciousness, informed consent was procured from caregivers [21]. Demographic data, injury specifics and clinical observations such as initial ED vital signs, neurological assessments, laboratory and radiology test results, in-hospital treatment details, and survival and functional status at discharge and during follow-up were all recorded in the PATOS-TBI registry. Following intracranial injury verification and study enrollment consent, ED staff collected blood samples for biomarker analysis. Functional outcomes over the long term were assessed through telephone surveys conducted at one- and six- months post-injury. To ensure the quality of the PATOS-TBI registry data, research coordinators were mandated to undergo initial and ongoing training throughout the study. The PATOS-TBI data quality control team conducted monthly verifications of the data entered.

2.2 Study population

Adult TBI patients over 18 years of age who visited participating EDs between December 2018 and March 2023 were enrolled. Patients with unknown information on long-term functional outcomes or obesity status were excluded.

2.3 Main outcomes

The primary outcome measures were disability and mortality at 6 months after injury. Secondary outcomes were disability and mortality at 1 month after injury. The evaluation of patient outcomes was based on the Glasgow Outcome Scale (GOS), which ranks results on a scale from 1 (indicating death) to 5 (indicating full recovery), with intermediate scores representing vegetative state, severe disability and moderate disability. A GOS score among 1, 2 or 3 was considered to reflect a state of disability. To determine these outcomes, structured interviews were administered by research coordinators at the five participating institutions, which assessed GOS scores, EuroQol 5-dimentsions (EQ-5D) ratings, and causes of mortality at the one- and six-month marks post-injury.

2.4 Variables and measurements

The main exposure, obesity, was defined as a body mass index (BMI) exceeding 25. Demographics and clinical findings at the ED were collected, including age, sex, comorbidities (hypertension, diabetes mellitus, coagulation disorder), mechanism of injury (road traffic injury, fall and others), place of injury (home, street and others), alcohol ingestion before injury, severity of injury (TBI and other region), injury severity score, vasopressor use, prehospital mental change, type of hemorrhage, advanced airway use, in-hospital transfusion and hospital outcomes.

2.5 Statistical analysis

We examined patient demographics, injury characteristics, injury characteristics, prehospital and hospital treatment, and study outcomes based on obesity status and sex. Categorical variables were analyzed using the Chi-square test, while continuous variables were assessed using the Wilcoxon rank-sum test. To assess the influence of obesity on disability and mortality at 1 and 6 months, we employed multilevel logistic regression analysis to compute both unadjusted and adjusted odds ratios (ORs) with 95% confidence intervals (CIs). The identification of potential confounders was guided by directed acyclic graph (DAG) models. Additionally, we conducted sensitivity analyses specifically targeting patients with very obese, defined as a body mass index (BMI) of 30 or above. Thereafter, we performed stratified analysis to examine whether the relationship between BMI and study outcomes varied according to sex. We checked for multicollinearity among the covariables in our model. All statistical evaluations were conducted with SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). A two-tailed p-value of less than 0.05 was deemed statistically significant.

3. Results

Out of 1206 patients collected during the entire study period, we ultimately enrolled a total of 1043 patients after excluding those who's BMI could not be confirmed, those who were underweight with a BMI of less than 18.5, or those whose study outcomes could not be determined.

3.1 Demographic findings

Table 1 presented the demographics according to BMI. In the group with a BMI over 25, there were a greater number

of younger patients, and there was no significant difference observed in emergency room mortality, or in 1-month and 6-month mortality rates. Table 2 presented the demographics according to sex. Male patients tended to be younger and were more likely to have experienced an injury away from home. Incidences of alcohol consumption at the time of injury were also significantly higher in men. Although the rates of mortality in the emergency department, at 1 month, and at 6 months were higher in males, the differences were not statistically significant.

3.2 Main outcomes

We performed multilevel logistic regression analysis using the normal weight group (BMI 18.5–25) as the reference. The outcomes for the group with a BMI over 25 showed no significant differences: 6-month disability (OR: 1.08, 95% CI (0.77–1.51)), 6-month mortality (OR: 1.41, 95% CI (0.67–2.93)). Additionally, when analyzing the over 25 BMI group, further divided into 25–30 and over 30 subgroups, no significant differences in outcomes were noted (Table 3). We conducted stratified analysis to determine the influence of BMI on study outcomes by sex. In the case of 1-month disability, male subjects with a BMI between 25–30 and those with a BMI over 30 showed no significant differences when compared to the reference group with a BMI of 18.5–25. However, female subjects with a BMI over 30 displayed a substantially higher disability outcome in contrast to the reference group, with an odds ratio of 4.53 (95% CI: 1.07–19.22) (Table 4) (**Supplementary Fig. 1**).

4. Discussion

Our study aimed to analyze the impact of obesity on the long-term prognosis of TBI and to investigate whether this association varies with sex. Our findings indicate that, across the entire population, obesity did not significantly influence mortality or disability rates at 1- or 6-months post-injury. However, sex-stratified analysis revealed that females with a BMI exceeding 30 showed higher disability rates (GOS 1–3) at 1 month compared to women with a normal BMI. This suggests a sex-specific vulnerability where obesity, particularly severe obesity in females, may increase the risk of poorer short-term outcomes after TBI. From a medical perspective, these findings highlight the importance of considering sex as a crucial factor when assessing the prognostic impact of obesity on TBI outcomes. Healthcare providers should recognize that obese female patients may require additional support and targeted interventions to optimize recovery trajectories, and a more nuanced approach may be necessary in the management and rehabilitation of TBI patients.

Obesity has emerged as a significant factor in the realm of TBI, impacting not just the likelihood of occurrence but also the severity and the recovery trajectory. Studies have shown that individuals with obesity are at a higher risk of falls, one of the primary causes of TBI, particularly in the elderly [22]. This increased risk is attributed to the greater challenge in maintaining balance and stability due to excess weight, which can lead to more frequent and potentially severe falls. Furthermore, once an injury occurs, those with obesity often face harsher consequences [23]. The comorbid conditions commonly associated with obesity, such as diabetes and hypertension, are thought to compromise cerebrovascular health, thus exacerbating the effects of brain injuries [24]. The recovery outcomes for obese individuals with TBI are also less favorable. The extended hospital stays and diminished functional recovery seen in this group may be due, in part, to a systemic pro-inflammatory state caused by obesity, coupled with the increased likelihood of accompanying comorbidities, all of which can hinder the healing process and complicate rehabilitation efforts. Therefore, the association between obesity and TBI presents a complex interplay of increased susceptibility, augmented injury severity, and impeded recovery, emphasizing the need for a nuanced approach to both prevention and treatment in this population [25]. In recent meta-analysis, obesity has been linked to a lower incidence but greater severity of head injuries, with obese patients experiencing longer hospital and intensive care unit (ICU) stays. Yet, it's not definitively shown that obesity provides any protective effect against the occurrence of head injuries. Additionally, the influence of obesity on long-term disability and mortality after a TBI has not been established as significant [26]. Our study's findings are consistent with this study, showing that even in very obese patients with a BMI over 30, the outcomes of TBI did not worsen in our sensitivity analysis [26].

Our study found that a BMI of 30 or more in female TBI patients was significantly associated with a higher incidence of disability at 1-month post-injury compared to those with a normal BMI. Possible explanations for this finding could include the chronic systemic inflammation often associated with obesity, which may exacerbate the inflammatory response after TBI, potentially leading to worse outcomes [27, 28]. Another explanation might be that obesity affects hormonal balance, particularly levels of estrogen, which could negatively impact neuroprotective effects [29]. Lastly, obesity may alter the response to stress hormones, affecting the recovery process after TBI through changes in the hypothalamic-pituitary-adrenal axis, suggesting that these factors, especially in female patients considering physiological and hormonal differences, could interact in complex ways to influence the incidence of disability [30, 31].

Our study comprehensively analyzed the impact of obesity on the long-term prognosis of patients with traumatic brain injury (TBI) and found that obesity did not significantly affect the mortality rate or disability at 1 and 6-months post-injury across the general population. While obesity was not observed to significantly influence the rate of disability in male patients, female patients with a BMI of 30 or above exhibited a higher rate of disability after one month compared to females with a normal BMI. From a medical perspective, these findings emphasize the need to consider gender-specific responses when assessing the impact of obesity on TBI prognosis, suggesting that recovery mechanisms, inflammatory responses, body composition and hormonal regulation in male patients may modulate the effects of obesity differently. Further research is necessary to better understand the influence of obesity on long-term outcomes in male patients, calling for a unique approach in their rehabilitation and management. A better understanding

TABLE 1. Demographics of study population according to body mass index.

Variables	All	Body Mass Index		
		BMI >25	BMI ≤25	*p*-value
	N (%)	N (%)	N (%)	
All	1043 (100.0)	275 (100.0)	768 (100.0)	
Hospital				
SNUH	54 (5.2)	14 (5.1)	40 (5.2)	
BRMH	17 (1.6)	6 (2.2)	11 (1.4)	
KNUH	279 (26.7)	65 (23.6)	214 (27.9)	0.431
CNUH	541 (51.9)	141 (51.3)	400 (52.1)	
CBNUH	152 (14.6)	49 (17.8)	103 (13.4)	
Age				
18–49	193 (18.5)	57 (20.7)	136 (17.7)	
50–59	170 (16.3)	57 (20.7)	113 (14.7)	
60–69	249 (23.9)	66 (24.0)	183 (23.8)	<0.001
70–79	267 (25.6)	66 (24.0)	201 (26.2)	
≥80	164 (15.7)	29 (10.5)	135 (17.6)	
Sex				
Female	301 (28.9)	76 (27.6)	225 (29.3)	0.431
Underlying disease				
Hypertension	330 (31.6)	82 (29.8)	248 (32.3)	0.411
Diabetes	249 (23.9)	67 (24.4)	182 (23.7)	0.688
Disorder of coagulation	16 (1.5)	(0.0)	16 (2.1)	0.021
Mechanism of injury				
Traffic	420 (40.3)	116 (42.2)	304 (39.6)	
Fall down	482 (46.2)	127 (46.2)	355 (46.2)	0.431
Other	141 (13.5)	32 (11.6)	109 (14.2)	
Place of injury				
Home	274 (26.3)	62 (22.5)	212 (27.6)	
Street	479 (45.9)	133 (48.4)	346 (45.1)	0.121
Other	290 (27.8)	80 (29.1)	210 (27.3)	
Alcohol ingestion before injury				
Yes	103 (9.9)	22 (8.0)	81 (10.5)	0.301
Severity (AIS ≥3)				
High AIS score of TBI	834 (80.0)	216 (78.5)	618 (80.5)	0.361
High AIS score of other region	186 (17.8)	57 (20.7)	129 (16.8)	0.132

TABLE 1. Continued.

Variables	All	Body Mass Index		
		BMI >25	BMI ≤25	*p*-value
	N (%)	N (%)	N (%)	
Severity of trauma (NISS)				
1–8	145 (13.9)	43 (15.6)	102 (13.3)	
9–15	341 (32.7)	93 (33.8)	248 (32.3)	0.321
16–24	276 (26.5)	61 (22.2)	215 (28.0)	
25–75	281 (26.9)	78 (28.4)	203 (26.4)	
Vasopressor				
Yes	41 (3.9)	9 (3.3)	32 (4.2)	0.569
Mental change				
Yes	455 (43.6)	102 (37.1)	353 (46.0)	0.012
Types of hemorrhage				
SDH	387 (37.1)	96 (34.9)	291 (37.9)	
SAH	294 (28.2)	76 (27.6)	218 (28.4)	
ICH	177 (17.0)	53 (19.3)	124 (16.1)	0.614
EDH	129 (12.4)	38 (13.8)	91 (11.8)	
IVH & other	56 (5.4)	12 (4.4)	44 (5.7)	
Advanced airway				
Yes	137 (13.1)	40 (14.5)	97 (12.6)	0.342
Transfusion				
Yes	139 (13.3)	34 (12.4)	105 (13.7)	0.731
Outcomes				
ED mortality	108 (10.4)	23 (8.4)	85 (11.1)	0.204
1-month GOS				
Death	134 (12.8)	31 (11.3)	103 (13.4)	
Vegetative state	11 (1.1)	5 (1.8)	6 (0.8)	
Severe disability	123 (11.8)	35 (12.7)	88 (11.5)	0.458
Moderate disability	92 (8.8)	25 (9.1)	67 (8.7)	
Good recovery	683 (65.5)	179 (65.1)	504 (65.6)	
6-month GOS				
Death	192 (18.4)	54 (19.6)	138 (18.0)	
Vegetative state	7 (0.7)	(0.0)	7 (0.9)	
Severe disability	65 (6.2)	17 (6.2)	48 (6.3)	0.341
Moderate disability	63 (6.0)	13 (4.7)	50 (6.5)	
Good recovery	716 (68.6)	191 (69.5)	525 (68.4)	

AIS: abbreviated injury scale; TBI: traumatic brain injury; NISS: new injury severity score; SDH: subdural hemorrhage; SAH: subarachnoid hemorrhage; ICH: intracranial hemorrhage; EDH: epidural hemorrhage; IVH: intraventricular hemorrhage; ED: emergency department; GOS: Glasgow outcome scale; SNUH, Seoul national university hospital, BRMH, Seoul national university boramae medical center; KNUH, Kyungpook national university hospital; CNUH, chonnam national university hospital; CBNUH, chungbuk national university hospital.

TABLE 2. Demographics of study population according to sex.

Variables	All	Sex		
		Male	Female	*p*-value
	N (%)	N (%)	N (%)	
All	1043 (100.0)	742 (100.0)	301 (100.0)	
Hospital				
SNUH	54 (5.2)	37 (5.0)	17 (5.6)	
BRMH	17 (1.6)	11 (1.5)	6 (2.0)	
KNUH	279 (26.7)	199 (26.8)	80 (26.6)	0.391
CNUH	541 (51.9)	378 (50.9)	163 (54.2)	
CBNUH	152 (14.6)	117 (15.8)	35 (11.6)	
Age				
18–49	193 (18.5)	166 (22.4)	27 (9.0)	
50–59	170 (16.3)	136 (18.3)	34 (11.3)	
60–69	249 (23.9)	173 (23.3)	76 (25.2)	<0.001
70–79	267 (25.6)	176 (23.7)	91 (30.2)	
≥80	164 (15.7)	91 (12.3)	73 (24.3)	
Underlying disease				
Hypertension	330 (31.6)	225 (30.3)	105 (34.9)	0.081
Diabetes	249 (23.9)	174 (23.5)	75 (24.9)	0.742
Disorder of coagulation	16 (1.5)	13 (1.8)	3 (1.0)	0.341
Body Mass Index				
Mean, SD	23.3 (3.3)	23.5 (3.3)	23.5 (3.3)	
Normal weight, BMI, 18.5–25	768 (73.6)	543 (73.2)	225 (74.8)	0.082
Overweight, BMI >25	275 (26.4)	199 (26.8)	76 (25.2)	
Mechanism of injury				
Traffic	420 (40.3)	303 (40.8)	117 (38.9)	
Fall down	482 (46.2)	336 (45.3)	146 (48.5)	0.601
Other	141 (13.5)	103 (13.9)	38 (12.6)	
Place of injury				
Home	274 (26.3)	180 (24.3)	94 (31.2)	
Street	479 (45.9)	344 (46.4)	135 (44.9)	<0.001
Other	290 (27.8)	218 (29.4)	72 (23.9)	
Alcohol ingestion before injury				
Yes	103 (9.9)	89 (12.0)	14 (4.7)	<0.001
Severity (AIS ≥3)				
High AIS score of TBI	834 (80.0)	585 (78.8)	249 (82.7)	0.124
High AIS score of other region	186 (17.8)	139 (18.7)	47 (15.6)	0.281

TABLE 2. Continued.

Variables	All	Sex		
		Male	Female	*p*-value
	N (%)	N (%)	N (%)	
Severity of trauma (NISS)				
1–8	145 (13.9)	106 (14.3)	39 (13.0)	0.283
9–15	341 (32.7)	236 (31.8)	105 (34.9)	
16–24	276 (26.5)	193 (26.0)	83 (27.6)	
25–75	281 (26.9)	207 (27.9)	74 (24.6)	
Vasopressor				
Yes	41 (3.9)	30 (4.0)	11 (3.7)	0.891
Mental change				
Yes	455 (43.6)	346 (46.6)	109 (36.2)	<0.001
Types of hemorrhage				
SDH	387 (37.1)	269 (36.3)	118 (39.2)	0.062
SAH	294 (28.2)	205 (27.6)	89 (29.6)	
ICH	177 (17.0)	121 (16.3)	56 (18.6)	
EDH	129 (12.4)	101 (13.6)	28 (9.3)	
IVH & other	56 (5.4)	46 (6.2)	10 (3.3)	
Advanced airway				
Yes	137 (13.1)	103 (13.9)	34 (11.3)	0.274
Transfusion				
Yes	139 (13.3)	101 (13.6)	38 (12.6)	0.701
Outcomes				
ED mortality	108 (10.4)	84 (11.3)	24 (8.0)	0.059
1-month GOS				
Death	134 (12.8)	102 (13.7)	32 (10.6)	0.021
Vegetative state	11 (1.1)	5 (0.7)	6 (2.0)	
Severe disability	123 (11.8)	96 (12.9)	27 (9.0)	
Moderate disability	92 (8.8)	70 (9.4)	22 (7.3)	
Good recovery	683 (65.5)	469 (63.2)	214 (71.1)	
6-month GOS				
Death	192 (18.4)	140 (18.9)	52 (17.3)	0.124
Vegetative state	7 (0.7)	3 (0.4)	4 (1.3)	
Severe disability	65 (6.2)	55 (7.4)	10 (3.3)	
Moderate disability	63 (6.0)	44 (5.9)	19 (6.3)	
Good recovery	716 (68.6)	500 (67.4)	216 (71.8)	

AIS: abbreviated injury scale; TBI: traumatic brain injury; NISS: new injury severity score; SDH: subdural hemorrhage; SAH: subarachnoid hemorrhage; ICH: intracranial hemorrhage; EDH: epidural hemorrhage; IVH: intraventricular hemorrhage; ED: emergency department; GOS: Glasgow outcome scale; SD, standard deviation; SNUH, Seoul national university hospital, BRMH, Seoul national university boramae medical center; KNUH, Kyungpook national university hospital; CNUH, chonnam national university hospital; CBNUH, chungbuk national university hospital.

TABLE 3. Multilevel logistic regression analysis for study outcomes according to BMI.

	Outcome	Model 1	Model 2	Model 3
	n/N (%)	OR (95% CIs)	OR (95% CIs)	OR (95% CIs)
6-month disability				
BMI, 18.5–25	193/768 (25.1)	1.00	1.00	1.00
BMI, ≥25	71/275 (25.8)	1.11 (0.81–1.53)	1.10 (0.79–1.52)	1.08 (0.77–1.51)
BMI, 18.5–25	193/768 (25.1)	1.00	1.00	1.00
BMI, 25–30	59/230 (25.7)	1.08 (0.76–1.52)	1.05 (0.75–1.49)	1.03 (0.72–1.47)
BMI, ≥30	12/45 (26.7)	1.32 (0.66–2.64)	1.35 (0.67–2.73)	1.41 (0.67–2.93)
6-month mortality				
BMI, 18.5–25	138/768 (18.0)	1.00	1.00	1.00
BMI, ≥25	54/275 (19.6)	1.24 (0.86–1.77)	1.21 (0.85–1.74)	1.20 (0.83–1.74)
BMI, 18.5–25	138/768 (18.0)	1.00	1.00	1.00
BMI, 25–30	45/230 (19.6)	1.20 (0.82–1.75)	1.17 (0.80–1.72)	1.15 (0.77–1.71)
BMI, ≥30	9/45 (20.0)	1.49 (0.69–3.21)	1.49 (0.69–3.25)	1.55 (0.69–3.48)
1-month disability				
BMI, 18.5–25	197/768 (25.7)	1.00	1.00	1.00
BMI, ≥25	71/275 (25.8)	1.06 (0.77–1.46)	1.05 (0.76–1.45)	1.03 (0.74–1.44)
BMI, 18.5–25	197/768 (25.7)	1.00	1.00	1.00
BMI, 25–30	59/230 (25.7)	1.03 (0.73–1.45)	1.02 (0.72–1.43)	0.99 (0.69–1.42)
BMI, ≥30	12/45 (26.7)	1.21 (0.61–2.42)	1.24 (0.62–2.48)	1.30 (0.63–2.70)
1-month mortality				
BMI, 18.5–25	103/768 (13.4)	1.00	1.00	1.00
BMI, ≥25	31/275 (11.3)	0.90 (0.58–1.39)	0.88 (0.57–1.36)	0.84 (0.54–1.32)
BMI, 18.5–25	103/768 (13.4)	1.00	1.00	1.00
BMI, 25–30	28/230 (12.2)	0.95 (0.61–1.50)	0.93 (0.59–1.46)	0.88 (0.56–1.41)
BMI, ≥30	3/45 (6.7)	0.59 (0.18–1.95)	0.59 (0.18–1.99)	0.58 (0.17–1.98)

Model 1: adjusted for age, sex; Model 2: adjusted age, sex, and comorbidities (hypertension and diabetes mellitus); Model 3: adjusted age, sex, comorbidities (hypertension and diabetes mellitus), preinjury disability, and injury severity (head AIS). OR: odds ratios; CIs: confidence intervals; BMI: body mass index.

of how biological characteristics and environmental factors in male patients interact with obesity may contribute to improving the management and prognosis of male TBI patients.

Our study has several limitations that should be considered when interpreting the results. First, the retrospective design of our research may contribute to inherent selection biases and limits our ability to establish causality between obesity and TBI outcomes. Second, the use of BMI as the sole measure of obesity does not account for the distribution of body fat or muscle mass, which could be significant factors in patient outcomes after TBI. Third, our study may not have captured all relevant confounding variables, such as pre-existing medical conditions, the severity of TBI, or the specifics of post-injury care, which could influence the long-term outcomes in patients with TBI.

5. Conclusions

Our study revealed a higher one-month disability rate in female TBI patients with a BMI over 30 compared to those with a normal BMI, highlighting the necessity for clinicians to be particularly vigilant when treating female TBI patients with a BMI over 30. While specific treatment protocols may not differ, the emphasis should be on intensifying the focus of care, recognizing the elevated risk profile, and being proactive in managing potential complications. It is imperative that healthcare providers are alert to the unique challenges posed by this group, ensuring that these patients receive dedicated attention and resources to optimize their care and outcomes.

TABLE 4. Stratified analysis of study outcomes by sex.

	Sex	
	Male (N = 742) Adjusted OR (95% CI)	Female (N = 301) Adjusted OR (95% CI)
6-month disability		
BMI, 18.5–25	1.00	1.00
BMI, ≥25	1.18 (0.79–1.75)	1.34 (0.43–2.55)
BMI, 18.5–25	1.00	1.00
BMI, 25–30	1.17 (0.77–1.79)	0.65 (0.30–1.41)
BMI, ≥30	1.20 (0.51–2.81)	2.15 (0.44–10.56)
6-month mortality		
BMI, 18.5–25	1.00	1.00
BMI, ≥25	1.40 (0.90–2.19)	0.83 (0.38–1.81)
BMI, 18.5–25	1.00	1.00
BMI, 25–30	1.45 (0.91–2.31)	0.65 (0.28–1.55)
BMI, ≥30	1.19 (0.45–3.19)	3.36 (0.66–17.16)
1-month disability		
BMI, 18.5–25	1.00	1.00
BMI, ≥25	0.95 (0.64–1.42)	1.29 (0.65–2.54)
BMI, 18.5–25	1.00	1.00
BMI, 25–30	0.97 (0.64–1.48)	1.08 (0.52–2.23)
BMI, ≥30	0.87 (0.37–2.08)	4.53 (1.07–19.22)
1-month mortality		
BMI, 18.5–25	1.00	1.00
BMI, ≥25	0.77 (0.45–1.31)	1.10 (0.45–2.73)
BMI, 18.5–25	1.00	1.00
BMI, 25–30	0.89 (0.52–1.53)	0.93 (0.35–2.50)
BMI, ≥30	0.20 (0.03–1.52)	2.95 (0.46–18.91)

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

AVAILABILITY OF DATA AND MATERIALS

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

EJ and YSR—conceptualization, had full access to all the data in the study, and take responsibility for the integrity of the data as well as the accuracy of the data analysis. GJP, HY, SGWL, EJ and SBM—data curation. EJ—formal analysis and software, funding acquisition, and writing original draft. YSR, SGWL, EJ and SBM— investigation. GJP, YSR and SDS—methodology. YSR and HHR—supervision. HY, SGWL, EJ and SBM—validation. GJP—visualization. YSR and HHR—writing—review and editing. All authors Approved final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the Institutional Review Board of all participating hospitals (IRB No.: SNUH-1806-078-951 (Seoul National University Hospital); CNUH-2018-297 (Chonnam National University Hospital); KNUH-2018-10-014-007 (Kyungpook National University Hospital); CBNUH-2018-09-018 (Chungbuk National University Hospital); BMC-30-2018-85 (Boramae Seoul Medical Center)). Informed consent was obtained from the patients, or legal representatives in cases where patients were unconscious.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jomh.org/files/article/1773598434606891008/attachment/Supplementary%20material.docx.

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