

# **The effects of obesity on outcomes in trauma injury: overview of the current literature**

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## **Abstract**

Obesity has reached epidemic proportions and is now considered a chronic disease by the National Institute of Health (NIH) in the West. Its impact on trauma outcomes is of particular interest with several studies presenting conflicting information. The present overview suggests a strong association between obesity and injury severity, hospital length of stay (LOS), intensive care unit (ICU) admission, pattern of injury, rate of complications and mortality. The nature of the observations may relate to an underlying physiological state of the obese patient and its associated comorbidities with a constant heightened inflammatory state aggravated by the second hit on an injury.

## **Keywords**

Review, Trauma, Injuries, Obesity, Outcomes

## **Background**

Obesity has increased in epidemic proportions in the West. Two out of every three adults are overweight and one out of every three adults are obese in the United States.<sup>1,2</sup> Metabolic and mechanical implications of increased total fat content include dyslipidemias, hypertension (HTN), insulin resistance state and their consequences, coronary artery disease (CAD), cerebral vascular accident (CVA), non-alcoholic steato-hepatitis (NASH), cancer, arthritis, and sleep apnea. These comorbidities can independently, or in association with other conditions, increase morbidity and mortality. Obesity and its impact on trauma outcomes is one of the main topics that has increased in popularity within the past decade although the current data presents conflicting information. The goal of this report is to perform an overview of the current literature and to determine the effect of body mass index (BMI) on trauma injuries.

## **Methods**

A systematic review was performed using PubMed (<https://www.ncbi.nlm.nih.gov/pubmed/>). Authors performed the search using key words *obesity AND trauma, BMI AND trauma*. The search included all pediatrics and adult articles published from January 2005 to February 2017. Case reports and review articles were excluded along with papers covering the psychological effects of trauma on children and also higher BMI during adulthood. The total number of papers that met our inclusion/exclusion criteria was 40 with the majority being retrospective chart reviews.

## **The effect of obesity on mortality in trauma injury**

Although some studies found no association between obesity and trauma, a cross-sectional study performed by Finkelstein et al. found the odds of sustaining an injury were 15-48% higher in over-weight and obese patients when compared to other groups.<sup>3</sup> In addition, Hoffmann et al. demonstrated increased mortality in obese patients suffering from poly-traumatic injury in Germany.<sup>4</sup> Bochicchio et al. found a 7.1 times increased hospital mortality rate in obese patients following trauma.<sup>5</sup> Moreover, this group demonstrated a two-fold increase in number of urinary tract, blood stream, and respiratory infections in the obese group. Similarly, Ditillo et al.

demonstrated that obese patients cataloged in National Trauma Databank had higher mortality after suffering a blunt trauma.<sup>6</sup> This study matched patients by using propensity score based on age, sex, injury severity score (ISS), Glasgow Coma Scale (GCS), and systolic blood pressure (SBP). In the former report, the obese group had longer hospital length of stay (LOS), intensive care unit (ICU) stay, and morbidity.

Alban et al. monitored the LOS for patients admitted to the surgical intensive care unit following trauma injury.<sup>7</sup> The ICU length of stay was higher in the obese group, but when regression analyses were performed, no association between BMI and mortality was observed. The former study may have failed to show such a correlation, obesity-to-mortality, due to a selection bias where patients evaluated were those admitted to surgical ICU and not those who expired from trauma either at the scene or emergency room (ER).

Diaz et al. noted morbid obesity was not a risk factor for mortality in trauma patients.<sup>8</sup> Groups were divided into obese with BMI > 40 kg/m<sup>2</sup> and non-obese with BMI < 30 kg/m<sup>2</sup>. While the study excluded patients with BMI in between (30 < BMI < 40), the protocol included only patients admitted to the hospital greater than three days. Patients with high BMI who expired at the scene, during transport, or in the emergency room were not evaluated, thus skewing the data towards no difference in observed outcomes.

### **The effect of BMI on recovery time in trauma injury**

Obese post-trauma patients may require longer recovery time following a procedure. A study conducted by Childs et al. reported that days in ICU and mechanical ventilation were significantly prolonged in obese patients.<sup>9</sup> These patients also had a much higher rate of complications such as acute kidney injury (AKI) and infections. Dhungel et al. used functional independence measurement (FIM) to measure the delay in recovery following trauma in patients.<sup>10</sup> They found that every 1 kg/m<sup>2</sup> increase in BMI correlated to decrease of 4% in FIM in obese patients (P < 0.001). Study of trauma patients that needed temporary abdominal closure (TAC) was done by Johnston et al.<sup>11</sup> LOS in ICU was significantly higher in patients with morbid obesity (BMI > 40) compared to patients with BMI < 25. They also required longer mechanical ventilation compared to patients with BMI < 18.5. This study did not find any difference in survival or type of abdominal closure between groups (stratified by BMI). They also concluded TAC can be used safely in trauma patients with BMI ≥ 30. Hyperglycemia following trauma is a well-known phenomenon, especially in patients suffering head trauma. Bonizzoli et al. studied this phenomenon in trauma patients without head trauma.<sup>12</sup> After conducting a propensity match to equate groups, they discovered that patients who presented with acute insulin resistance post injury had a significantly higher BMI, C-reactive protein, and leukocyte counts suggesting that monitoring insulin resistance can predict outcomes in the obese patient group.

The rate of associated injuries and complications is increased in the obese patient when compared to non-obese patient with trauma. Decubitus ulcer development and wound complications rose by 4-8 and 2.5-4 folds respectively amongst severely obese patients.<sup>13</sup> Same

patients were 30% more likely to die and approximately two times more likely to have a major complication. Livingston et al. reported obese patients undergoing laparotomy were associated with increased LOS in the ICU as well as increased rates of respiratory and renal failure, bacteremia, and abdominal wound dehiscence.<sup>14</sup> Nonetheless once logistic regression was performed on their data, BMI was not seen to be an independent predictor for morbidity in this group. Serrano et al. found obesity to be an independent risk factor for pulmonary and wound infections after controlling for variables such as ISS, age, ICU LOS, and multiple comorbidities.<sup>15</sup>

Rhabdomyolysis is one complication that patients may experience after traumatic injury. In a retrospective study done by Chan et al., patients with BMI of 25 and higher, who suffered trauma (especially blunt trauma from MVC), were found to have a significantly higher risk of developing rhabdomyolysis.<sup>16</sup> As a result, authors recommend aggressive monitoring of creatinine kinase levels in this patient population. Acute kidney injury (AKI) post trauma is one of the most common sources of morbidity and poor outcome in patients. Shashaty et al. published risk factors for the development of AKI included obesity, being of African-American descent, and blood products given.<sup>17</sup>

Obese patients after trauma are at higher risk for deep venous thrombosis (DVT) and possible pulmonary embolism (PE), which could lead to an increase chance of mortality. Patients following trauma have shown to be at a hypercoagulable state. Kornblith et al. conducted a prospective study to evaluate clotting factor levels in obese patients post injury.<sup>18</sup> They found significantly higher platelet counts at times of admission as well as higher levels of factor IX, but lower D-dimer levels. Clot strength and functional fibrinogen levels were also higher in obese patients. Using regression logistics, they found for every 5-kg/m<sup>2</sup> increase in BMI, there is an 85% increased odds of thromboembolic complications in these patients. Such conditions were also demonstrated in the obese patient by Frezza et al.<sup>19</sup> Obesity is known to be a state that increases the chance of venous thromboembolism. Slower recovery, immobility, and being bedridden are some of the other reasons behind obesity and pro-thrombotic state. Similarly, Ho et al. found higher BMI to be one of the important risk factors for fatal PE in patients post trauma.<sup>20</sup> Other major risk factors identified were severity of injuries and existence of comorbidities in patients. It is the standard of care to categorize obese patients after trauma as high risk for thromboembolism (TE) and pulmonary embolus (PE) events and also to exercise preventive measurements, i.e. low molecular weight heparin (LMWH) and/or pneumatic compression as indicated.

In severe trauma patients, organ perfusion could be compromised for various reasons that would jeopardize a patient's life. It was demonstrated by Belzberg et al. that cardiac index was significantly lower in elderly and obese patients, which correlates with their survival.<sup>21</sup> In order to prevent hypoxemia and tissue damage, patients were transfused with packed red blood cells (RBC) at a lower threshold. De Jong et al. demonstrated that obesity was directly related to a higher rate of massive transfusion ( $\geq 10$  U of packed RBC) even though the groups had similar trauma associated hemorrhage scores.<sup>22</sup>

### **The effect of BMI in pediatric trauma population**

Obesity in pediatric population is a topic that has been evaluated by some researchers since implications of childhood obesity on pediatric trauma have not been well studied. Witt et al. found in their study that obese children had a significantly longer length of stay in hospital and use of ventilators.<sup>23</sup> They further showed higher BMI was associated with increased rate of pneumonia, DVT, PE, and mortality. Similarly, Rana et al. found that DVT and decubitus ulcers were higher in obese children.<sup>24</sup> They found that obese children had higher rates of extremity fractures that required operative intervention, which placed them at a higher risk for complications (DVT and decubitus ulcers). Interestingly, they found lower incidence of intracranial and intra-abdominal injuries in obese children.

Pulmonary fat embolism (PFE) in pediatric trauma was the focus of study done by Eriksson et al.<sup>25</sup> BMI was identified to be independently associated with increased PFE in children after trauma. Alselaim et al. evaluated the effects of obesity on trauma outcomes in the pediatric population.<sup>26</sup> This study divided children by the 95<sup>th</sup> percentile for BMI and found no significant association between obesity and mortality. The criteria used to separate the two groups may have included overweight or near obese patients in the control group leading to no observed difference in outcomes. However, this study reported a significant difference in the pattern of injury patients suffered among groups, obese vs non-obese groups. High BMI pediatric patients were more likely to sustain rib and pelvic fractures and to have higher Injury Severity Score (ISS) following trauma.

### **The effect of BMI in injury patterns and recovery time**

Previous studies have shown obese patients suffer a distinct pattern of injury when compared to non-obese patients. Brown et al. identified that obese patients suffer fewer head injuries, but more chest and lower extremity injuries after trauma.<sup>27</sup> Additionally, the obese group possessed significantly higher morbidity and mortality rates. Using stepwise regression analysis, authors revealed obesity to be an independent risk factor for mortality. Similarly, Pal et al. evaluated patients less than 60 years of age involved in MVCs from the side with no airbag deployment. Patients with increased BMI were not at increased risk for head injuries but were more likely to experience lower extremity injuries.<sup>28</sup> Rupp et al. reported head-on MVCs to be associated with higher risk for lower and upper extremity injuries, as well as spinal injuries in obese patients.<sup>29</sup> Obesity is associated with increased anterior abdominal fat content and as such, could serve as a protective factor for abdominal blunt and penetrating injuries. Bloom et al. evaluated chest and abdomen abbreviated injury scale (AIS).<sup>30</sup> Increased BMI was found to protect patients against abdominal stab wounds and to have lower need for an operation. Osborne et al. evaluated outcomes in obese patients who suffered penetrating injury, fall injury, and motor vehicle collisions (MVC).<sup>31</sup> In this study, obese patients who were injured by falls and MVCs sustained fewer head injuries. The mortality rate was lowest in obese patients who had fall injury compared to the other two groups. The MVC group had a higher LOS in the hospital whereas penetrating trauma was associated with no difference in outcome. Obesity was concluded to be a protective factor in patients with falls. A retrospective study conducted by Evans et al. found that in older patients (>45yo), the BMI was associated with higher torso and proximal upper extremity injuries.<sup>32</sup> However, BMI was not an independent risk factor for complications or

mortality in older patients. Vincent et al. evaluated recovery time in patients suffering from orthopedic trauma by assessing functional independence measure (FIM), walking distance, and climbing stairs.<sup>33</sup> Total and motor FIM scores were lower at discharge for obese patients. Moreover, even though improvement in FIM was seen using rehabilitation protocols, it was significantly at lower magnitude when compared to non-obese patients.

Motor vehicle collisions are one of the mainstays of morbidity and mortality in traumatic patients. Seatbelts and airbags have led to decrease in severity of injuries and deaths. In an attempt to find any significance in use of safety precautions by obese passengers, Joseph et al. determined mortality was 1.52 times higher in morbidly obese motorists.<sup>34</sup> This was the same in the three study groups (non-restrained, seatbelt, seatbelt and airbag). The anatomy and physiology of the oropharynx in obese patients are different than in the non-obese. Interestingly Sifri et al. showed in their three-year long prospective study at a level I trauma center, that obesity was not a risk factor for intubation on patients.<sup>35</sup> Nonetheless, higher BMI was associated with a statistically higher rate of early respiratory complications. The abdomen is one major area that injuries could occur. Two major organs, liver and spleen, are located in this area that could jeopardize patients' outcomes in a traumatic event. Vaughan et al. in a prospective study done in pediatric populations, tried to investigate the effect of obesity on abdominal injuries.<sup>36</sup> They found that overall mean injury severity scale (ISS) and abdominal abbreviated injury score (AIS) were significantly higher in obese children. Most importantly they demonstrated that obese children suffered significantly higher liver lacerations (injury) than non-obese. They hypothesized this to be the result of hepatic steatosis that makes liver more prone to injury. Regardless of BMI, they found no difference in non-operative management of patients.

### **The effect of BMI on the systemic inflammatory response and its associated comorbidities**

Inflammatory markers' association and function in response to trauma have been studied. Ciesla et al. performed a prospective study demonstrating an increase in multi organ failure (MOF) rate, using the Denver multiple organ failure score for obese patients compared to non-obese patients.<sup>37</sup> Additionally, obesity was found to be an independent risk factor for the development of MOF. Obese patients were more likely to be admitted to the ICU and to have greater length of hospital stay. However, mortality was significantly increased in this group. Patient selection criteria excluded isolated head injuries, which may increase the mortality rate. This group theorizes that the constant heightened inflammatory state created by obesity leads to higher rate of MOF in the obese group. Similarly, Christmas et al. showed a four-fold increase in mortality rate for morbidly obese patients following trauma injury.<sup>38</sup> Obese patients had a longer hospital stay and higher rate of MOF. The development of MOF was a significant risk factor for mortality in the obese patient group. To combat the development of MOF, Winfield et al. evaluated the novel use of angiotensin converting enzyme inhibitor (ACEI) and angiotensin receptor blockers (ARBs) in managing obese traumatic patients due to fundamental comprehension of obesity pathophysiology.<sup>39</sup> In obese patients, angiotensin II (ATII) level was higher. Monocytes also contain ATII receptors on their surface and as a result are under direct influence of this system. Obese patients who received ACEI/ARBs not only showed improved T-

cell function and monocyte maturation, but also demonstrated lower Marshall and Denver Scores for the development of MOF. The use of ACEI or ARBs in severely injured obese patients may represent a novel therapeutic target to improve outcomes following trauma injury.

Obesity leads to a chronically heightened inflammatory response. In a multicenter study done by Edmonds et al., outcome of patients suffering blunt injury who had hemorrhagic shock was evaluated.<sup>40</sup> They found as BMI increased, rate of MOF also increased. This was mainly in cardiac, respiratory, and renal systems. They found for every increase of 1 kg/m<sup>2</sup> in BMI value, risk of MOF and nosocomial infections (NI) increased by 9% and 7% respectively. BMI was concluded to be an independent risk factor for MOF and NI.

### **In-vitro and in-vivo trauma studies**

Diebel et al. attempted to assess how the role of gender impacts the adipocytes response to stress.<sup>41</sup> Adipocytes were supplemented with either estrogen (E<sub>2</sub>) or testosterone (DHT) in-vitro and subsequently, exposed to epinephrine and hypoxia/re-oxygenation scenarios in order to emulate stress in-vivo. In the control group (no hormone exposure), the levels of tumor necrosis factor- $\alpha$  (TNF- $\alpha$ ) and interleukin-6 (IL-6) were increased following stress simulation. However, adipocytes exposed to physiologic levels of estrogen demonstrated decreased levels of TNF- $\alpha$  and IL-6 while adipocytes exposed to testosterone showed increased TNF- $\alpha$  and IL-6 levels similar to the control group. This dimorphism at the cellular level could help explain the differences in outcomes for obese patients following trauma in regards to gender.

Comorbidities associated with obesity such as metabolic syndrome and non-alcoholic fatty liver disease are found to be major risk factors for poor outcomes in obese patients following trauma. Matheson et al. explored this concept in small animal models.<sup>42</sup> They demonstrated that obesity in rats impaired blood flow to the liver and kidneys, thus, leading to higher circulation of inflammatory markers (IL-1, IL-6, and human mobility group box-1(HMGB-1)). Additionally, obese rats suffered worse outcomes due to trauma regardless of injury severity. Traumatic injury worsened liver and renal functions in obese rats compared to the non-obese group.

### **Conclusion**

Injuries from blunt trauma have always been a major cause of mortality and morbidity. Obesity on the other hand is a newer phenomenon that is on the rise. Careful examination of current literature can help to reveal the close impact of obesity in patients suffering blunt trauma. Obesity both as an independent factor (by presence of comorbidities), as well as directly by creating physical forces, affects outcome of patients undergoing blunt trauma. As presented in this literature, even though some conflicting results exist, the majority of publications show an intimate association between the two. Worse injury scale with specific patterns, higher ICU admissions, longer hospital stay, and higher mortality rates were amongst the observations in obese patients who suffered blunt trauma. This review also examined several studies that have attempted to shine light on this association by studying the pathophysiology of both obesity and trauma. One major finding is heightened inflammatory state created by obesity that plays a pivotal role in outcome of patients who have undergone trauma. Studying and analyzing this

situation can have major implications with possible improvement in management strategies of patients at the scene as well as in the hospital.

Abbreviations	
ACEI	Angiotensin Converting Enzyme Inhibitor
AIS	Abbreviated Injury Scale
AKI	Acute Kidney Injury
ARBs	Angiotensin Receptor Blockers
ATII	Angiotensin-II
BMI	Body Mass Index
CAD	Coronary Artery Disease
CVA	Cerebro Vascular Accident
DHT	Dihydro testosterone (testosterone)
DVT	Deep Venous Thrombosis
ER	Emergency Room
E <sub>2</sub>	Estrogen
FIM	Functional Independence Measurement
GCS	Glasgow Coma Scale
HMGB-1	Human Mobility Group Box-1
HTN	Hypertension
ICU	Intensive Care Unit
IL-6	Interleukin-6
ISS	Injury Severity Score
LMWH	Low Molecular Weight Heparin
LOS	Length of Stay
MOF	Multi-organ Failure
MVC	Motor Vehicle Collision
NI	Nosocomial Infection
NIS	National Institute of Health
PE	Pulmonary Embolism
PFE	Pulmonary Fat Embolism
RBC	Red Blood Cells
SBP	Systolic Blood Pressure
TAC	Temporary Abdominal Closure
TE	Thromboembolism
TNF- $\alpha$	Tissue Necrosis Factor- $\alpha$

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