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Research Article

Impact of Body Mass Index on the Mortality of Critically Ill Patients Admitted to the Intensive Care Unit: An Observational Study

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Abstract

Background: Obesity is a severe multifactorial disorder that carries high morbidity and mortality.
Objectives: This study aimed to evaluate the possible association between body mass index (BMI) and mortality in patients admitted to intensive care units (ICU).
Methods: In this cross-sectional study, all patients admitted to the ICU were studied. The demographic characteristics, ICU, and hospital length of stay, organ failure, mortality, duration of mechanical ventilation, the occurrence of nosocomial infection, and type of admission were recorded for all patients. Patients were categorized based on their BMI.
Results: In total, 502 patients were studied who 53.2% of them were male. Most of the death (28.6%) were recorded in the obesity class II patients, while the lowest rate (3.9%) was for the normal-weight patients (P value < 0.001). The APACHE II and waist circumference had a statistically significant association with the mortality rate (P value < 0.001). After adjusting for age and gender, a significant association was found between waist circumference and mortality rate (OR = 1.15, 95% CI = 1.03 - 1.29; P value = 0.014), APACHE II score, and mortality rate (OR = 2.79, 95% CI = 1.91 - 4.07, P value < 0.001); but there was no significant association between BMI and mortality rate.
Conclusions: This study demonstrated that BMI is associated with an increased risk of mortality, regardless of age and gender. However, after adjusting for age and gender as confounding factors, BMI didn't have a significant effect on mortality, while the APACHE II score and waist circumference affected the mortality rate.

Keywords: Intensive Care Units, Mortality, Body Mass Index, Waist Circumference, Critically Ill Patients

1. Background

Obesity is a severe multifactorial disorder that is strongly associated with several life-threatening complications (1). As a growing health concern, it's estimated that 2.1 billion people are affected by obesity all around the world, and it also claims 3.4 million lives each year (2). It's well-documented that a sedentary lifestyle is associated with an increased prevalence of obesity (3). There are various ways to define obesity (4). Body fat is a simple divide of body weight (kg) and height (m^2), which is called body mass index (BMI). Based on the World Health Organization (WHO) classification, a BMI over 25 is overweight, and a BMI over 30 is obese (5). It's well-documented that overweight is a causative agent of hypertension, diabetes, hyperlipidemia, cancer, and pulmonary disorders (6-8).

On the other hand, comorbidities have a significant effect on the prognosis of critically ill patients (9). That is the reason why the scoring systems used in the survival assessment of critically ill patients, including the acute physiology and chronic health evaluation (APACHE) II and III, simplified acute physiology score (SAPS) II, and Mortality Probability models (MPM II), all have emphasized on the underlying comorbidities by dedicating considerable scores (10, 11). Hence, regardless of the effects of obesity on critically ill patients' prognosis, obesity can worsen the conditions of patients by triggering other serious health issues.

There is substantial controversy regarding the effects of obesity on the mortality, morbidity, and hospital length of stay (LOS) in critically ill patients admitted to the intensive care unit (ICU) (12). Meanwhile, as a merely adjustable risk factor, obesity could come in handy in accurately assessing the prognosis of ICU-admitted patients and preventing a remarkable amount of ICU deaths.

2. Objectives

An important association exists between BMI and almost every category of mortality outcome. In contrast to some previous evidence suggesting that overweight might be protective, some studies showed that the risk began to increase with overweight for most outcomes, including all-cause mortality. So, this study aimed to determine the association between BMI and mortality of critically ill patients admitted to the ICU.

3. Methods

3.1. Study Design and Population

In this cross-sectional study, all patients admitted to two university-affiliated ICUs from November 2017 to March 2019 were included. Exclusion criteria were having a previous history of ICU admission, unwillingness to participate, and lack of complete height and weight records at the time of admission.

Age, gender, BMI, APACHE II score, type of admission (medical, surgical or trauma), comorbidities, history of malignancy or immunodeficiency and diabetes, ICU stay, hospital LoS, organ failure during the admission (based on the sequential organ failure assessment (SOFA) score), the status of respiratory, cardiovascular, hepatic, renal, and central nervous systems and coagulation, mortality rate, duration of mechanical ventilation or vasopressor-therapy, type of nutrition, site of infection (if present), and reintubation/extubation failure were recorded for all patients. Data were collected by observation and reviewing documents and records of patients in the ICU (Nursing handover records, paper-based inpatient medical records, and ward admission discharge records).

3.2. Anthropometric Measurements

The weight of all patients was recorded using a weighbridge during the ICU admission. Waist circumference (WC) was performed after removing clothes around the abdomen and hips, holding the tape measure between the midpoint of the last palpable rib and the iliac crest, while breathing out normally and bringing the tape around the waist. The tape was not held too tight or loose, and WC was measured with a tape straight around the back while the abdomen relaxed, the arms at the side, the feet together, and at the end of a normal expiration, without the tape compressing the skin. Edema, resuscitation, abdominal surgeries, and skill of nurses performing the measurement were considered as confounding factors. As we performed WC measurements on the first day of ICU admission, it seems that the possibility of the first two factors will be less. Having a history of abdominal surgery was an exclusion criterion. Moreover, by training the nurses, we tried to minimize the inter/intraobserver variability.

3.3. Statistical Analysis

Data were analyzed using SPSS version 16 and reported as mean $\pm$ standard deviation for the continuous variables and percentage for discrete variables. The Kolmogorov-Smirnov test and descriptive statistics were used to assess the normality of the variables. The chi-square test was used to analyze the differences between categorical variables. To assess the differences between the groups, one-way ANOVA and Kruskal-Wallis tests were used for parametric and non-parametric variables, respectively. To investigate the association between WC, BMI, and APACHE II score and the mortality rate, the logistic regression was conducted by considering the age and gender of the patients. The findings are presented as odds ratios (ORs) using a 95% confidence interval (CI). A P value of < 0.05 was considered statistically significant.

3.4. Ethical Considerations

Written informed consent was obtained from all patients or their relatives. The study protocol was approved by the Ethics Committee of the university, which is in compliance with the Declaration of Helsinki. Participants were ensured about the confidentiality of the information, and the data were analyzed using a coded format. No additional charge was received from participants, and they were informed that they can withdraw from the study at any time.

4. Results

Out of 525 medical records, 23 were excluded due to incompleteness of information. Of 502 eligible patients, 267 (53.2%) were male. The mean age of participants was 59.42 $\pm$ 11.48 years. The mean weight was 72.18 $\pm$ 13.144 kg, for WC, it was 82.67 $\pm$ 8.577 cm, and for the blood level of albumin, it was 3.46 $\pm$ 0.26. The median hospital and ICU LoS was seven and four days, respectively. Seventy-six patients had a positive history of diabetes, who 30 of them were type 1 diabetes. The demographic characteristics of patients and the outcomes of the study are summarized in Table 1.

The highest mortality rate (28.6%) was observed among the obesity class II patients ($35 < \text{BMI} < 40$), while the lowest rate (3.9%) was observed in the normal-weight patients

Table 1. Demographic Characteristics of Patients (N = 502)[a]

Variables	Group (BMI)					Total	P Value
	Underweight (< 18.5)	Normal-Weight (18.5 - 25)	Overweight (25 - 30)	Obesity Class I (30 - 35)	Obesity Class II (35 - 40)		
Number of patients	39	256	130	56	21	502	
Gender							
Female	7 (17.9)	107 (41.8)	75 (57.5)	32 (57.1)	14 (66.7)	235 (46.8%)	
Male	32 (82.1)	149 (58.2)	55 (42.3)	24 (42.9)	7 (33.3)	267 (53.2%)	
Waist circumference	74.10 ± 10.285	80.61 ± 7.871	84.32 ± 6.527	89.16±9.299	96.29 ± 11.310	82.67 ± 8.577	< 0.001
Mortality	8 (20.5)	10 (3.9)	21 (16.2)	12 (21.4)	6 (28.6)	57 (11.3)	< 0.001
Length of hospital stay, median	6	6	7	12	8	7	< 0.001
Duration of stay in the intensive care unit, median	6	4	4	9	5	4	< 0.001
APACHE II score	22.08 ± 6.247	18.99 ± 2.919	20.94 ± 4.446	21.88 ± 5.387	21.90 ± 5.567	20.18 ± 4.291	< 0.001
Hospital infection	18 (46.2)	63 (24.6)	36 (27.7)	19 (33.9)	6 (28.6)	142 (28.2)	< 0.05
History of malignancy	24 (61.5)	16 (6.3)	1 (0.8)	4 (7.1)	1 (4.8)	46 (9.1)	< 0.001
Reintubation	7 (17.9)	20 (7.8)	15 (11.5)	21 (37.5)	6 (28.6)	69 (13.5)	< 0.001
Extubation failure	4 (10.3)	10 (3.9)	7 (5.4)	13 (23.2)	5 (23.8)	39 (7.7)	< 0.001
Type of nutrition							< 0.001
Parenteral	24 (61.5)	20 (7.8)	10 (7.7)	4 (7.1)	10 (47.6)	68 (13.5)	
Enteral	15 (38.5)	236 (92.2)	120 (92.3)	52 (92.9)	11 (52.4)	434 (86.5)	
Type of admission							< 0.001
Medical	5 (12.8)	106 (41.4)	58 (44.6)	20 (35.7)	2 (9.5)	191 (38.0)	
Surgical	31 (79.5)	81 (31.6)	40 (30.8)	19 (33.9)	18 (85.7)	189 (37.4)	
Trauma	3 (7.7)	69 (27.0)	32 (24.6)	17 (30.4)	1 (4.8)	122 (24.3)	

[a]Values are expressed as No. (%) or mean ± SD.

(18.5 < BMI < 25) (P value < 0.001). The mean APACHE II score was 20.18 ± 4.291, and for patients with and without mortality, it was 30.21 ± 3.22, and 18.89 ± 2.20, respectively (P value < 0.001). Of 502 patients, 142 (28.2%) developed nosocomial infection. A logistic regression model was constructed, which led to the following results: the mortality rates in patients with abdominal infection, pulmonary infection, and skin infection were, respectively, 5.92, 4.73, and 3.77 times higher and statistically significant (P value < 0.05). The association between the mortality rate and urinary tract infection, catheter infection, and brain infection was not statistically significant. Based on the results of the ANOVA test, patients with a BMI of less than 18.5 and a BMI between 18.5 and 25 had the highest and lowest APACHE II score, respectively (P value < 0.001). Patients with a BMI of less than 18.5 and a BMI between 35 and 40 had the lowest and highest WC, respectively, based on the ANOVA test (P value < 0.001). The Kruskal-Wallis test showed that the duration of vasopressor-therapy was the highest in patients with a BMI between 35 and 40; while the lowest rate was observed for patients with a BMI between 18.5 and 25 (P value < 0.001). The mechanical ventilation duration was the lowest in patients with a BMI of 35 to 40, with an average of 11.57 days; while the highest value was observed in patients with a BMI of 18.5 to 25 with an average of 2.50 days (P value < 0.001). The results of the logistic regression indicated a statistically significant association between WC and mortality rate, in which for each cm increase in the WC, the patients' chances of mortality was increasing by 1.15 (OR = 1.15, 95% CI = 1.03 - 1.29, P value = 0.014). Also, the association between APACHE II score and the mortality rate was statistically significant, as per each unit of increase in APACHE II score, the mortality rate was increasing by 2.79 (OR = 2.79, 95% CI = 1.91 - 4.07, P value < 0.001). The impact of BMI on mortality rate was not found statistically significant after adjusting for age and gender.

5. Discussion

In this study, the highest mortality rate was observed in patients with a BMI between 35 and 40 (obesity class II), and the lowest rate was observed in patients with a BMI between 18.5 and 25 (normal-weight patients). Obesity is a major contributor to the development and progression of numerous disorders, many of them may result in patients' death (13). Notwithstanding, there is a point of conflict, whether BMI is a proper representation of obesity in predicting mortality-related outcomes. The evidence regarding the association between BMI and mortality rate are conflicting, as some studies have shown no significant association, while some reported an increase or decrease in patients' mortality (14, 15). In a prospective study aimed to evaluate the effect of obesity on the mortality of patients admitted to ICU in Saudi Arabia, the authors reported that the mortality rate in overweight critically ill patients was lower than patients with normal-weight, despite identical severity of the illness (16). A retrospective study conducted in the United States reported that patients with a BMI > 40 and patients with a BMI < 20 had a higher hospital LoS (17). They concluded that a lower BMI is associated with an increased mortality rate and worsened functional status at the time of discharge. A cohort of 699 patients also demonstrated that the obese patients have lower in-hospital mortality, though the findings were not witnessed among the older group of the obese patients, which suggests the need for further studies to elaborate the possible association between age, obesity, and fatal outcomes in ICU patients (18).

In a cohort study in the United Kingdom, Nasraway et al. (19) showed that a BMI > 40 was an independent cause of death in ICU-admitted surgery patients. It was concluded that severe obesity is a risk factor for mortality of ICU patients in similar conditions regarding age, sex, and severity of the disease. Although in the present study we didn't have a group for those with a BMI > 40, the highest mortality rate was still observed in most obese patients.

On the other hand, several studies have reported no association between BMI and mortality of critically ill patients. Supporting this claim, a recent study showed that although obesity decreases the need for intubation and inotropic support, evidence are not sufficient to support the increasing or decreasing mortality of patients (20). Another study on 312 patients with sepsis and acute respiratory failure showed that even though overweight and obese patients had an increased LoS in both hospital and ICU, there was no association between BMI and mortality rate (21). Likewise, a study conducted by Lewis et al. (22) on the patients admitted to an adult medical ICU with more than 24 hours of stay reported that overweight and obesity were not related to ICU mortality. Still, obesity was significantly associated with longer LoS and increased comorbid illness. Recent studies are implemented on larger populations, with different subgroups, and have considered the etiological context (20, 23). A recent dose-response meta-analysis on the effect of BMI on the mortality of ICU-admitted patients showed that for each unit of increase in BMI, a 0.6% decrease in mortality rate is expected (24). This study also discussed that while a BMI > 35 is a high risk feature in ICU-admitted patients, a BMI < 35 can play a protective role against mortality. The discrepancy between the results can be attributed to the differences in study designs, ethnicity, classification of BMI, comorbidities, type of ICU admission, and physiological severity of the illness. The present study also showed that per each unit of increase in APACHE II score and WC, the risk of mortality increases by 2.79 and 1.15, respectively, which indicates that WC can better predict this value than BMI. The results of several studies are in line with the findings of the present study. An observational study evaluated the mortality of 403 ICU patients and reported that unlike the BMI, higher WC is a risk factor for mortality of critically ill patients (25). Also, a recent pooled analysis of 11 prospective cohort studies with a total of 650,000 participants with a median of nine-year follow-up, discussing the association between WC and mortality, concluded that higher WC is significantly associated with higher mortality, and even for patients with a normal BMI, WC could still be a prognostic factor for risk assessment (26). Regarding the association of BMI and hospital infection, the present study demonstrated that patients with a BMI < 18.5 had the highest rate of hospital infection, while patients with a normal-BMI had the lowest rate. A retrospective cohort study by Papadimitriou-Olivgeris et al. reported similar findings (27).

A study, with the main focus of investigating the role of obesity in the prognosis of sepsis patients, revealed that obesity had a direct impact on some morbidities, including bloodstream infection and *Klebsiella pneumonia* colonization, and concluded that obesity affects sepsis in ICU patients. Regarding the association between high BMI and mortality in ARDS patients, studies showed an interesting result, which is known as the obesity paradox, meaning that morbid obese ARDS patients have lower mortality compared to normal patients. In obesity, the high chest wall elastance could redistribute regional transpulmonary pressure, possibly reducing the potential negative effects of mechanical ventilation in an inhomogeneous lung (28).

However, any positive association between obesity and survival may be outweighed by the volume of data linking obesity with a great number of severe illnesses. In cases with uncertainty, physicians should not overlook the clear risk-lowering effects of weight reduction in obese individuals who are at a higher risk of different disorders and complications. Despite the conflicting results about the association between BMI and mortality, recent studies showed that WCs is an independent risk factor for mortality in critically ill patients and reported a significant negative association between WC and mortality (29). The present study also demonstrated that BMI may be associated with mortality, without considering WC and APACHE score, but once these variables were considered as confounding factors, no association was observed between BMI and morbidity.

While the current study benefited from an adequate study duration and proper sample size, the follow-up period was limited. Therefore, further studies with larger sample sizes, longer follow-up duration, and with the evaluation of long-term outcomes among different BMI groups are recommended. Moreover, conducting studies based on types of admission (medical, surgical, or trauma) and on specific subgroups of age, gender, and ethnicities may result in more explicit and clear findings.

5.1. Conclusions

This study demonstrated that BMI may be associated with mortality, regardless of age and gender. However, after controlling for age and gender, BMI did not have a significant effect on mortality, while the APACHE II score and WC affected the mortality rate.

Footnotes

Authors' Contribution: SS and AM equally contributed to the conception and design of the research. MSH and FK contributed to the acquisition and analysis of the data. AI and SS contributed to the analysis and interpretation of the data. AM and MSH drafted the manuscript. All authors critically revised the manuscript, agree to be fully accountable for ensuring the integrity and accuracy of the work, and read and approved the final manuscript.

Conflict of Interests: The authors declare no conflicts of interest.

Ethical Approval: The study protocol was approved by the Ethics Committee of the Tabriz University of Medical Sciences. Issues emphasized in the Declaration of Helsinki, and its subsequent amendments were observed. Patients were ensured about the confidentiality of the results. Besides, the data were analyzed using a coded format (ethical code: 5/666882 TBZMED).

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Informed Consent: Written informed consent was obtained from all patients or their relatives.

References

1. Smith KB, Smith MS. Obesity statistics. *Prim Care*. 2016;**43**(1):121–35. ix. doi: 10.1016/j.pop.2015.10.001. [PubMed: 26896205].
2. Hales CM, Carroll MD, Fryar CD, Ogden CL. Prevalence of obesity and severe obesity among adults: United States, 2017-2018. *NCHS Data Brief*. 2020:360.
3. Flashner BM, Rifas-Shiman SL, Oken E, Camargo CA, Platts-Mills TJ, Workman L, et al. Obesity, sedentary lifestyle, and exhaled nitric oxide in an early adolescent cohort. *Pediatr Pulmonol*. 2020;**55**(2):503–9. doi: 10.1002/ppul.24597. [PubMed: 31805224]. [PubMed Central: PMC6980304].
4. Bjorntorp P. Definition and classification of obesity. *Eating disorders and obesity: A comprehensive handbook*. **2**. Guilford Press; 2002. p. 377–81.
5. Piche ME, Poirier P, Lemieux I, Despres JP. Overview of epidemiology and contribution of obesity and body fat distribution to cardiovascular disease: An update. *Prog Cardiovasc Dis*. 2018;**61**(2):103–13. doi: 10.1016/j.pcad.2018.06.004. [PubMed: 29964067].
6. Vucenik I, Stains JP. Obesity and cancer risk: evidence, mechanisms, and recommendations. *Ann N Y Acad Sci*. 2012;**1271**:37–43. doi: 10.1111/j.1749-6632.2012.06750.x. [PubMed: 23050962]. [PubMed Central: PMC3476838].
7. Peters U, Suratt BT, Bates JHT, Dixon AE. Beyond BMI: Obesity and lung disease. *Chest*. 2018;**153**(3):702–9. doi: 10.1016/j.chest.2017.07.010. [PubMed: 28728934]. [PubMed Central: PMC5989645].
8. Mokdad AH, Ford ES, Bowman BA, Dietz WH, Vinicor F, Bales VS, et al. Prevalence of obesity, diabetes, and obesity-related health risk factors, 2001. *JAMA*. 2003;**289**(1):76–9. doi: 10.1001/jama.289.1.76. [PubMed: 12503980].
9. Zampieri FG, Colombari F. The impact of performance status and comorbidities on the short-term prognosis of very elderly patients admitted to the ICU. *BMC Anesthesiol*. 2014;**14**:59. doi: 10.1186/1471-2253-14-59. [PubMed: 25071415]. [PubMed Central: PMC4112835].
10. Sekulic AD, Trpkovic SV, Pavlovic AP, Marinkovic OM, Ilic AN. Scoring systems in assessing survival of critically Ill ICU patients. *Med Sci Monit*. 2015;**21**:2621–9. doi: 10.12659/MSM.894153. [PubMed: 26336861]. [PubMed Central: PMC4562616].
11. Karim MR, Ahmed F, Fatema K, Ahsan A, Begum T, Mahmud MR, et al. A comparison of severity systems APACHE II and SAPS II in critically ill patients. *Bangladesh crit care J*. 2013;**1**(1):27–32. doi: 10.3329/bccj.v1i1.14362.
12. De Jong A, Verzilli D, Sebbane M, Monnin M, Belafia F, Cisse M, et al. Medical versus surgical ICU obese patient outcome: A propensity-matched analysis to resolve clinical trial controversies. *Crit Care Med*. 2018;**46**(4):e294–301. doi: 10.1097/CCM.0000000000002954. [PubMed: 29293153].
13. Abdelaal M, le Roux CW, Docherty NG. Morbidity and mortality associated with obesity. *Ann Transl Med*. 2017;**5**(7):161. doi: 10.21037/atm.2017.03.107. [PubMed: 28480197]. [PubMed Central: PMC5401682].
14. Flegal KM, Ioannidis JP, Doehner W. Flawed methods and inappropriate conclusions for health policy on overweight and obesity: The global BMI mortality collaboration meta-analysis. *J Cachexia Sarcopenia Muscle*. 2019;**10**(1):9–13.
15. Klatsky AL, Zhang J, Udaltsova N, Li Y, Tran HN. Body mass index and mortality in a very large cohort: Is it really healthier to be overweight? *Perm J*. 2017;**21**:16–142. doi: 10.7812/TPP/16-142. [PubMed: 28678695]. [PubMed Central: PMC5499607].
16. Aldawood A, Arabi Y, Dabbagh O. Association of obesity with increased mortality in the critically ill patient. *Anaesth Intensive Care*. 2006;**34**(5):629–33. doi: 10.1177/0310057X0603400501. [PubMed: 17061639].

17. Tremblay A, Bandi V. Impact of body mass index on outcomes following critical care. *Chest*. 2003;**123**(4):1202–7. doi: 10.1378/chest.123.4.1202. [PubMed: 12684312].
18. Trivedi V, Jean RE, Genese F, Fuhrmann KA, Saini AK, Mangulabnan VD, et al. Impact of obesity on outcomes in a multiethnic cohort of medical intensive care unit patients. *J Intensive Care Med*. 2018;**33**(2):97–103. doi: 10.1177/0885066616646099. [PubMed: 27139008].
19. Nasraway SJ, Albert M, Donnelly AM, Ruthazer R, Shikora SA, Saltzman E. Morbid obesity is an independent determinant of death among surgical critically ill patients. *Crit Care Med*. 2006;**34**(4):964–70. quiz 971. doi: 10.1097/01.CCM.0000205758.18891.70. [PubMed: 16484910].
20. Davis ET, Xie L, Levenbrown Y. Impact of obesity on outcomes in critically Ill children. *JPEN J Parenter Enteral Nutr*. 2017:148607117725043. doi: 10.1177/0148607117725043. [PubMed: 28793199].
21. Juarez E, Edriss H, Lear M, Sanchez A, Yang S, Nugent K. The association between body mass index and outcomes in patient with sepsis and acute respiratory failure. *The Southwest Respiratory and Critical Care Chronicles*. 2019;**7**(31):13–23. doi: 10.12746/swrccc.v7i31.615.
22. Lewis O, Ngwa J, Kibreab A, Phillpotts M, Thomas A, Mehari A. Body mass index and intensive care unit outcomes in african American patients. *Ethn Dis*. 2017;**27**(2):161–8. doi: 10.18865/ed.27.2.161. [PubMed: 28439187]. [PubMed Central: PMC5398175].
23. Pauzenberger R, Radtke C, Ederer IA, Hacker S, Waldmann A, Sternat N, et al. Does obesity impact the outcome of severely burned patients? *Int Wound J*. 2020;**17**(2):380–6. doi: 10.1111/iwj.13282. [PubMed: 31898396]. [PubMed Central: PMC7064920].
24. Khalooeifard R, Djafarian K, Safabakhsh M, Rahmani J, Shab-Bidar S. Dose-response meta-analysis of the impact of body mass index on mortality in the intensive care unit. *Nutr Clin Pract*. 2020. doi: 10.1002/ncp.10473. [PubMed: 32181950].
25. Paolini JB, Mancini J, Genestal M, Gonzalez H, McKay RE, Samii K, et al. Predictive value of abdominal obesity vs. body mass index for determining risk of intensive care unit mortality. *Crit Care Med*. 2010;**38**(5):1308–14. doi: 10.1097/CCM.0b013e3181d8cd8b. [PubMed: 20228682].
26. Cerhan JR, Moore SC, Jacobs EJ, Kitahara CM, Rosenberg PS, Adami HO, et al. A pooled analysis of waist circumference and mortality in 650,000 adults. *Mayo Clin Proc*. 2014;**89**(3):335–45. doi: 10.1016/j.mayocp.2013.11.011. [PubMed: 24582192]. [PubMed Central: PMC4104704].
27. Papadimitriou-Olivgeris M, Aretha D, Zotou A, Koutsileou K, Zbouki A, Lefkaditi A, et al. The role of obesity in sepsis outcome among critically Ill patients: A retrospective cohort analysis. *Biomed Res Int*. 2016;**2016**:5941279. doi: 10.1155/2016/5941279. [PubMed: 27777948]. [PubMed Central: PMC5061945].
28. Zhi G, Xin W, Ying W, Guohong X, Shuying L. "Obesity paradox" in acute respiratory distress syndrome: Asystematic review and meta-analysis. *PLoS One*. 2016;**11**(9). e0163677. doi: 10.1371/journal.pone.0163677. [PubMed: 27684705]. [PubMed Central: PMC5042414].
29. Cho GJ, Yoo HJ, Hwang SY, Choi J, Lee KM, Choi KM, et al. Differential relationship between waist circumference and mortality according to age, sex, and body mass index in Korean with age of 30-90 years; a nationwide health insurance database study. *BMC Med*. 2018;**16**(1):131. doi: 10.1186/s12916-018-1114-7. [PubMed: 30092838]. [PubMed Central: PMC6085614].