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# Predicting COVID-19 outcomes with the Edmonton Obesity Staging System

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**BACKGROUND:** Multiple studies have demonstrated a correlation between a high body mass index and discriminatory COVID-19 outcomes. Studies appear to indicate that there is a correlation between obesity-related comorbidities and less favorable outcomes.

**OBJECTIVES:** The primary aim of the current investigation is to conduct a thorough assessment of the correlation between BMI and comorbidities associated with obesity, and their potential impact on the severity and consequences of COVID-19 infection among patients receiving care in a tertiary healthcare setting.

**DESIGN:** Retrospective cohort

**SETTINGS:** Tertiary rehabilitation center, Riyadh, Saudi Arabia

**PATIENTS AND METHODS:** The study included all individuals who received medical treatment and tested positive for COVID-19 by means of RT-PCR during the period from March to September 2020. COVID-19 patients were classified using Edmonton Obesity Staging System (EOSS).

**MAIN OUTCOME MEASURES:** COVID-19-related complications, including pneumonia and cytokine release syndrome, as well as the time length to COVID-19 negativization.

**SAMPLE SIZE:** 315 patients

**RESULTS:** The median (25th-75th percentiles) age of the patients was 38 (31.5-49) years old. Males outnumbered females, and 66% of patients were non-Saudis. Forty-eight patients (15.2%) had obesity class I, whereas 13 patients (4.1%) had class II. Thirty-two patients (10.2%) were classified as EOSS stage 1, 105 patients (33.3%) were classified as EOSS stage 2, and 25 patients (7.9%) were assigned to EOSS stage 3. Males predominated in EOSS stages 1 and 2, whereas females predominated in stage 3. In EOSS stage 3, 52% of cases had moderate severity and 48% had severe illness.

**CONCLUSIONS:** EOSS distinguishes the COVID-19 risks of poor outcomes beyond BMI. Patients who were overweight or obese but remained in the stage 1 of the EOSS had a lower risk of a poor COVID-19 outome than normal-weight patients. The health status of obese patients is a more precise indicator of the progression of COVID-19 during hospitalization than BMI alone.

**LIMITATIONS:** Given the limited capacity of urgent care facilities to conduct a comprehensive evaluation of comorbidities and other relevant outcomes in all patients, it is plausible that certain patients may have been erroneously classified with an EOSS stage 2 diagnosis, when in fact they ought to have been assigned a stage 3 diagnosis.

**CONFLICT OF INTEREST:** None.

Obesity is a progressive condition ushered in by disproportionate fat buildup that increases the chance of developing health problems.[1] In clinical settings, body mass index (BMI) is used as a marker of overweight and obesity,[2] yet the measurement is not a precise indication of health status because it does not represent obesity-related health concerns, comorbidities, or functional impairments,[3,4] especially when comorbidities pertaining to obesity increase morbidity, mortality, and healthcare expenditures.[5]

To overcome this, the Edmonton Obesity Staging System (EOSS) 1 was developed in 2009 to quantify the extent of weight-related health impairment in patients with obesity.[6] The EOSS is a five-stage obesity measure and serves as a surrogate measure of obesity-related comorbidities such as type 2 diabetes and hypertension.[6] Since its development, the EOSS has been validated in various cohorts,[7,8] and incorporated into many guidelines such as the 2020 Canadian clinical practice guideline for obesity in adults that underscores the importance of conducting an in-person clinical evaluation of individuals grappling with obesity, incorporating both obesity classification (as determined by body mass index) and disease stage (as determined by the EOSS).[9]

Although SARS-CoV-2 generally brings about only mild illness in the general population, people with particular vulnerabilities, including the elderly and obese, are susceptible to more severe forms of the disease, which are characterized by respiratory failure and multiorgan failure.[10]

Obesity and overweight have been predictive of COVID-19-related acute outcomes and have been associated with increased risk of premature mortality and hospitalization.[11] Undoubtedly, obesity constitutes a state of low-grade proinflammation that triggers immune dysregulation, leading to a compromised ability of the body to combat respiratory infection caused by COVID-19, thereby aggravating the health condition.[12] On the other hand, obesity-related comorbidities such as type 2 diabetes and hypertension have also been shown to be independent predictors of COVID-19 severity when included in studies involving BMI.[13,14]

Therefore, the potential correlation between the degree of obesity-related comorbidity and BMI, and its impact on COVID-19 outcomes, could be further elucidated by conducting an evaluation of the comorbidities experienced by overweight or obese COVID-19 patients, using the EOSS framework. Healthcare providers who engage in proactive counseling with COVID-19 patients, who are susceptible to unfavorable outcomes due to elevated BMI measurements, stand to gain from a heightened comprehension of this correlation.

Due to a lack of research in Saudi Arabia and other Middle Eastern nations, the objectives of the present study were to conduct a thorough assessment of the correlation between BMI and comorbidities associated with obesity (as determined by EOSS), and their potential impact on the severity and consequences of COVID-19 infection among patients receiving care in a tertiary healthcare setting in Riyadh.

## PATIENTS AND METHODS

This was a retrospective cohort study that was conducted at Sultan Bin Abdul Aziz Humanitarian City in Riyadh, Saudi Arabia, during the interval ranging from April 2020 to August 2021. All patients who were hospitalized and had a confirmed case of COVID-19 disease as determined by a RT-PCR assay were considered eligible for inclusion. Women who were pregnant, patients with cancer, and those who had immunodeficiency illnesses were not eligible for the study. The subjects in the cohort were first divided into three groups, one for each BMI category, that include: (1) those with a BMI of 20-24.9 kg/m$^2$, labeled "normal weight;" (2) those with a BMI of 25-29.9 kg/m$^2$, labeled "overweight;" and (3) subjects with a BMI greater than 30 kg/m$^2$, labeled "obese."[15] After that, the group of obese people was separated into three different classes: Class I, which corresponds to a BMI range of 30-34.9 kg/m$^2$; Class II, which corresponds to a BMI range of 35-39.9 kg/m$^2$; and Class III, which corresponds to a BMI of 40 kg/m$^2$.[16] Baseline parameters such as gender, body mass index, hypertension, dyslipidemia, and asthma were included in the study as independent variables. Biochemical measures including glucose, creatinine, alanine aminotransferase, aspartate aminotransferase, ferritin, and D-dimer. COVID-19 related complications including pneumonia and cytokine release syndrome. Covid-19 disease severity was also reported as severe or moderate.

### *Determination of the EOSS stage in study participants*

Based on the COVID-19 patients' admission data, the EOSS classification was determined. Individuals in the initial phases of EOSS exhibited standard readings for blood pressure, fasting glucose, total cholesterol, triglycerides, creatinine, and liver enzymes, and had not necessitated any antecedent medical intervention or pharmacological agents. Individuals exhibiting systolic blood pressure readings ranging from 130 to 139 mmHg, diastolic blood pressure readings ranging from 80 to 90 mmHg, fasting glucose levels ranging from 100 to 125 mg/dL, and/or HbA1c lev-

els ranging from 5.8 to 6.4% have been categorized as belonging to the initial stage of obesity as per the Edmonton Obesity Staging System (EOSS). As shown in **Appendix 1**.

Patients were diagnosed and/or treated for various health conditions based on the EOSS, including type 2 diabetes mellitus, hypertension, dyslipidemia, blood glucose levels above 126 mg/dL, non-fasting glucose levels above 200 mg/dL, Hb1Ac levels above 6.5%, total cholesterol and triglyceride levels above 200 mg/dL, and elevated liver enzymes, with the help of medication. Patients in the third stage of EOSS had a serum creatinine level more than 1.12 mg/dL, elevated liver enzymes, and/or clinical symptoms of cardiovascular sickness. Patients in their latter stages of cancer, cardiovascular, renal, or liver disease are eligible for EOSS's final fourth stage.[17] No patients in this study underwent the studies to determine whether that might be in the fourth stage.

### *Statistical analysis*

According to the appropriateness of the statistical approach for the data distribution, the clinical features of the research population were reported using appropriate statistical measures, includingthe median (with interquartile ranges or 25th-75th percentiles), and number and prevalence percentages (%). To identify specific risk variables linked with negative outcomes in individuals with a BMI of 25 kg/m$^2$, the research performed stratified analyses based on several categories, including normal weight (BMI 25 kg/m$^2$), overweight (BMI 25-29.9 kg/m$^2$), and obesity (BMI 30 kg/m$^2$). Analysis of variance (ANOVA) was used to compare the clinical characteristics and biomarkers of patients with normal weight to those of patients with different EOSS stages. Days-to-negative survival analysis was performed using a Cox proportional risk regression model, stratified by BMI categories and EOSS phases. Data were presented as odds ratio and 95% confidence interval of clinical outcomes, including pneumonia (yes vs no), cytokine release syndrome (yes vs no) and COVID severity (severe vs moderate) in patients with different categories of BMI considering 'normal weight' as reference. Multivariate logistic regression analysis was done to produce the table. Model 'a', 'b' and 'c' represents adjustment with age, gender, and comorbidities (hypertension, diabetes, dyslipidemia, and asthma), respectively. IBM SPSS) version 21.0 (Armonk, NY, USA: IBM Corp) was used for statistical analysis. Results were considered statistically significant when the *P* value was less than .05.

## RESULTS

The median (25th-75th percentiles) age of the 315 patients evaluated was 38.0 (31.5-49.0 years), with most patients (60%) falling in the age bracket of 31-50 years (**Table 1**). The number of males was slightly higher than the rate of females and more than 66% of the patients were non-Saudis. About one-third (31.1%) of the patients were overweight, whereas nearly half (153, 48.6%) were of normal weight (BMI, 20–24.9 kg/m$^2$). There were 48 patients (15.2%) with class I obesity, and just 13 patients (4.1%) with class II obesity. Forty patients (12.7%) had no EOSS stage 0 disease. A total of 32 patients (10.2%) were classified as EOSS stage 1, 105 patients (33.3%) were classified as EOSS stage 2 and 25 patients (7.9%) were assigned to EOSS stage 3.

**Table 2** shows the baseline characteristics of the patients according to different BMI categories. The mean age did not differ significantly between different categories, however, patients in obesity class I, II, and III were older than the patients with normal weight or those who were overweight. The rate of males and females did not differ significantly across all the BMI categories, except for class I obesity (10.64% versus 22.05%). The rate of pneumonia and cytokines release was the highest among the overweight group and obesity class I patients at 41.02% and 22.50% versus 30.76% and 25.00% respectively. This was also observed with the rate of severe cases, where the highest was among patients in the overweight group and obesity class I (37.50% and 29.27%), while the highest rate of moderate cases was among patients with normal weight. Except for the overweight group, the rate of severe cases was significantly higher than moderate cases across all BMI categories **Table 3** summarizes patient outcomes and clinical features by EOSS stage. Patients in stage 1 of EOSS were marginally younger than those in stages 2 and 3. Males were substantially more prevalent in EOSS stages 1, and 2, whereas females dominated in EOSS stage 3 (60% versus 40%). The average body mass index (BMI) of patients with EOSS phases 1-3 was 30.84 (27.0-33.0) kg/m$^2$, which is 8 kg/m$^2$ higher than the BMI of normal-weight individuals. Patients with EOSS stages 1 and 2 were more likely to be in obesity class I (65.62% vs. 65.72%, respectively) if they were obese. This was not the case for EOSS stage 3, in which 44% of patients were classified as obese. The rate of complications, namely diabetes mellitus, hypertension, and dyslipidemia was significantly different between all the EOSS stages and significantly higher than EOSS stage 0. In stages 1 and 2, hypertension was the most prevalent complication

**Table 1.** Characteristics of patients (n=315).

| | |
|---|---|
| Age (years) | 38.0 (31.5-49) |
| Age categories | |
| 18 -30 years | 67 (21.3) |
| 31-50 years | 189 (60.0) |
| 51-60 years | 40 (12.7) |
| >60 years | 19 (6.0) |
| Gender | |
| Male | 188 (59.7) |
| Female | 127 (40.3) |
| Nationality | |
| Saudi | 104 (33.0) |
| Non-Saudi | 211 (67.0) |
| Body mass index | |
| Normal weight | 153 (48.6) |
| Overweight | 98 (31.1) |
| Obesity class I (30–34.9 kg/m$^2$) | 48 (15.2) |
| Obesity class II (35–39.9 kg/m$^2$) | 13 (4.1) |
| Obesity class III (≥ 40 kg/m$^2$) | 3 (1.0) |
| Edmonton Obesity Staging System | |
| EOSS stage 1 | 32 (10.2) |
| EOSS stage 2 | 105 (33.3) |
| EOSS stage 3 | 25 (7.9) |
| Blood pressure classification | |
| Normal <120 and <80 mmHg | 96 (30.5) |
| Prehypertension 120–139 or 80–89 mmHg | 149 (47.3) |
| Stage 1 Hypertension 140–159 or 90–99 mmHg | 58 (18.4) |
| Stage 2 Hypertension ≥160 or ≥100 mmHg | 12 (3.8) |
| Severity | |
| Mild | 274 (87.0) |
| Severe | 41 (13.0) |

Data are median (25th-75th percentiles) for continuous data (age) and number (percentage) for categorical data.

followed by dyslipidemia. The third most prevalent consequence for both stages was diabetes mellitus.

**Table 4** demonstrates the association of different EOSS stages with pneumonia, cytokines release syndrome, and COVID severity. In the univariate model, EOSS stage 1 was associated with more than twelve times increased risk of pneumonia with this association being significant in the multivariate-adjusted models. Additionally, stage 1 was associated with more than four times increased risk of cytokine release syndrome, while this association was not statistically significant in the adjusted models. Stage 1 was also associated with a significantly increased risk of COVID-19 severity in all the models. Stage 2 was associated with a significantly increased risk of pneumonia and COVID severity in the univariate and adjusted models. However, this association was not significant with cytokines release syndrome. EOSS stage 3 was associated with markedly and significantly increased risk of pneumonia, cytokine release syndrome, and COVID severity.

Being overweight was independently and significantly associated with an increased risk of pneumonia, and COVID-19 severity in univariate, age, and gender-adjusted models. This association increased with higher BMI categories, where obesity class I was associated with 10.7 times increased risk of pneumonia (<.001) and 7.3 times increased risk of severe COVID-19 infection (*P*=.007). This significant and independent association was even higher with obesity classes II and III, except for the comorbidities-adjusted model for the cytokines release syndrome (.101) as presented in **Table 5**.

Time to COVID-19 negativization was determined following World Health Organization guidelines, which measure the duration between the onset of symptoms confirmed by a positive RT-PCR test and the day of the second consecutive negative RNA SARS-CoV-2 test result.[18] Normal-weight patients cleared the virus in 8.86 (0.16) days, a significantly shorter duration than patients in EOSS stage 1 or EOSS stage 3 who cleared the virus 12.65 (0.98) and 20.81 (3.36) days on average respectively (**Figure 1**).

## DISCUSSION

The widespread effects of the COVID-19 pandemic on people's physical and mental health have brought to light the role that preexisting chronic conditions play in the development of infectious complications associated with illness.[19] The relationship between COVID-19 and the ongoing obesity global epidemic is the focus of this research. We analyzed the correlation between categories of BMI and the prevalence of EOSS and COVID-19. This draws attention to the need of discern-

**Table 2.** Baseline characteristics and outcomes according to the BMI classes.

| Parameters N (%) | Normal weight (N=153) | Overweight n (%) (N=98) | Obesity class I (30–34.9) (N=48) | Obesity class II (35–39.9) (N=13) | Obesity class III (≥40 kg/m²) (N=3) | *P* value (rows) |
|---|---|---|---|---|---|---|
| Age (years) | | | | | | |
| Mean (SD) | 40.25 (11.33) | 41.22 (11.87) | 42.97 (13.73) | 43.61 (10.86) | 42.0 (18.01) | .07 |
| Gender (%) | | | | | | |
| Male (188) | 95 (50.53) | 62 (32.98) | 20 (10.64) | 10 (5.32) | 1 (0.53) | |
| Female (127) | 58 (45.67) | 36 (28.35) | 28 (22.05) | 3 (2.36) | 2 (1.57) | .043 |
| *P* value (columns) | .193 | .384 | .005 | .195 | .351 | |
| Complication (%) | | | | | | |
| Pneumonia (39) | 4 (10.25) | 16 (41.02) | 12 (30.76) | 5 (12.82) | 2 (5.12) | .049 |
| Cytokine RS (30) | 5 (12.50) | 9 (22.5) | 10 (25) | 4 (10) | 12 (30) | |
| Severity (%) | | | | | | |
| Moderate (275) | 148 (53.82) | 83 (30.18) | 36 (13.09) | 7 (2.54) | 1 (.36) | |
| Severe (40) | 5 (12.19) | 15 (37.50) | 12 (29.27) | 6 (14.63) | 2 (4.87) | <.0001 |
| *P* value (columns) | <.001 | .255 | .007 | .003 | .005 | |

ing between healthy and concurrent diseases in people who are overweight or obese so that their risk of undesirable COVID-19 outcomes may be determined and the relevant preventative measures can be practiced. This study discovered that among COVID-19 patients who were admitted to the hospital and had BMIs in the overweight or obese range, there was a direct correlation between the severity of obesity-related health conditions, as defined by the EOSS stage, and the likelihood of experiencing negative clinical outcomes. In contrast, BMI alone did not exhibit such a predictive capacity. It is of utmost significance to note that the cohort of patients who were admitted to the hospital and exhibited an increased BMI but lacked significant comorbidities associated with obesity, commonly referred to as EOSS stage (0), did not experience an unfavorable clinical outcome as per the findings of this study. It appears that individuals without comorbidities are seemingly safeguarded against the adverse clinical consequences of COVID-19 contraction compared with patients with an elevated BMI who are recognized to be at a heightened susceptibility to unfavorable COVID-19 outcomes. This is attributed to the fact that patients with comorbidities are significantly more probable to have a poor prognosis for COVID-19 infection. These findings align with those of Tsoulis et al in 2022, wherein they assessed the prognostic value of BMI and comorbidity burden associated with obesity in a group of COVID-19 patients admitted to the hospital. Their results indicate that the latter factor serves as a more reliable predictor of unfavorable outcomes.[20]

Our results are consistent with recent data from Mexico, which employed EOSS to assess the prevalence of obesity-related comorbidities in COVID-19 patients with a high BMI.[21] In contrast to BMI, the subsequent studies revealed that obesity-related conditions, as measured by EOSS, were associated with worse COVID-19 outcomes. Numerous studies have demonstrated a clear link between BMI and adverse COVID-19 outcomes. Nevertheless, the degree to which coexisting medical conditions related to obesity were taken into account in these studies exhibits variability.[22-24]

Individuals at various phases of the EOSS continuum who possess a BMI equal to or over 25 kg/m² have a higher risk of encountering complications compared to those with a BMI equal to or less than 25 kg/m². The previously mentioned resemblance has attracted significant notice. Patients with a normal body weight exhibited lower risks for severe disease symptoms, such as established comorbidities, pneumonia, and cytokine release syndrome, to overweight and obese patients in EOSS stages 2, 3, and 4. Notably, despite being less prone to diabetic complications, high blood pressure, high cholesterol, and asthma, these patients still faced similar risks for severe disease symptoms.

**Table 3.** Baseline characteristics and outcomes according to the Edmonton Obesity Staging System stages.

| Parameters | Normal weight (N=153) | Stage 1 (n=32) | Stage 2 (n=105) | Stage 3 (n=25) | *P* value |
|---|---|---|---|---|---|
| Age (years) | 40.2 (11.3) | 40.46 ( 10.0) | 41.88 (12.2) | 42.56 (15.3) | .114 |
| Gender | | | | | |
| Male | 95 (62.1) | 22 (68.7) | 61 (58.1) | 10 (40.0) | .132 |
| Female | 58 (37.9) | 10 (31.2) | 44 (41.9) | 15 (60.0) | |
| *P* value (male vs female) | < .0001 | .0029 | .0193 | .1615 | |
| BMI (kg/m$^2$) | 22.0 (21.0-25.0) | 28.0 (26.0-32.0) | 27.0 (26.0-31.0) | 30.84 (27.0-33.0) | **<.0001** |
| Normal weight | 153 (100) | - | - | - | - |
| Overweight | - | 21 (65.62) | 69 (65.71) | 8 (32.00) | **<.0001** |
| Obesity class I (30–34.9) | - | 8 (25.0) | 29 (27.62) | 11 (44.00) | |
| Obesity class II (35–39.9) | - | 3 (9.37) | 7 (6.67) | 3 (12.00) | |
| Obesity class III (≥40) | - | - | - | 3 (12.00) | |
| Comorbidities | | | | | |
| Hypertension | 6 (3.9) | 8 (25.0) | 20 (28.6) | 6 (24.0) | **.0100** |
| Diabetes mellitus | 6 (3.9) | 3 (9.4) | 13 (12.4) | 6 (24.0) | |
| Dyslipidemia | 8 (5.2) | 4 (12.5) | 17 (16.2) | 5 (20.0) | |
| Asthma | 1 (0.6) | 1 (3.1) | 3 (2.8) | 3 (12.0) | |
| Complications | | | | | |
| Pneumonia | 4 (2.6) | 7 (21.9) | 16 (15.2) | 12 (48.0) | .474 |
| Cytokine release syndrome | 5 (3.3) | 4 (12.5) | 8 (7.6) | 13 (52.0) | |
| *P* value (columns) | 0.7367 | 0.3243 | 0.0833 | 0.7795 | |
| The severity of disease at admission for Covid-19 | | | | | |
| Moderate | 148 (96.7) | 24 (93.8) | 89 (84.8) | 13 (52.0) | **.0001** |
| Severe | 5 (3.3) | 8 (6.2) | 16 (15.2) | 12 (48.0) | |
| *P* value (columns) | <.0001 | <.0001 | <.0001 | 0.7795 | |

Data are median (interquartile range) for continuous data (age) and number (percentage) for categorical data.

Irrespective of the patient's body weight, this observation remained consistent. The present finding is in line with epidemiological investigations that have established that only those patients who exhibit normal weight manifest a decreased likelihood of necessitating mechanical ventilation in comparison to patients with class III obesity.[25] Furthermore, subjects exhibiting EOSS stages 0 and 1 demonstrated a comparatively diminished relative hazard of mortality compared to patients of standard weight.[26]

Multiple correlations between BMI and COVID-19 outcomes have been found. Malik et al conducted a systematic study to ascertain the prevalence of COVID-19 and adverse outcomes in individuals over the age of 50 with a BMI of less than 25 kg/m$^2$ and of various ages.[27] Conversely, findings from Kaiser Permanente Southern California, a vast integrated healthcare network, have revealed a heightened correlation between COVID-19 fatality and adiposity among the younger demographic.[28] Elevated hazards were correlated with the exacerbation of infections, a surge in hospitalizations, an unfavorable prognosis, and a rise in mortality, particularly among elderly individuals with comorbidities.[29] Several hypotheses can explain why obese individuals have a lower survival rate than non-obese individuals. The elevated, low-grade inflammatory state

of obesity is associated with an ineffective adipose microenvironment. The adipose cells secrete adipokines that are pro-inflammatory in nature, including but not limited to tumor necrosis factor-alpha (TNF-alpha) and interleukin-6. Furthermore, there is a decrease in the levels of adiponectin and an increase in the levels of leptin. The pathogenesis of multiple organ failure may commence with a dysregulated cytokine milieu.[30] Therefore, there is inconsistency in the relationship between BMI and adverse COVID-19 outcomes; nonetheless, most studies have found that the relationship is substantial for BMIs over 35 kg/m$^2$ and considerably greater for BMIs above 40 kg/m$^2$. The pathophysiological processes of obesity, which include inflammation and metabolic abnormalities, are not captured by BMI.[31,32] The evaluation of the said mechanisms serves to elucidate potential hazards, such as the exacerbation of COVID-19 severity due to hyperglycemia-induced reactive oxygen species production, immune response dysregulation, and glycemic downturn.[33,34] The EOSS, which classifies obesity based on medical, mental, and/or functional complications rather than BMI, is a better predictor of mortality across all possible causes, and may better characterize COVID-19 patients' risk of hyperinflammation. According to Chiappetta et al, there is an elevation of IL-6 in individuals who are metabolically obese (EOSS 2 and 3). The same study also found a significant correlation between C-reactive protein and waist-to-hip ratio. This research suggests that physicians treating COVID-19 patients should consider such factors since early identification of hyperinflammation can help reduce mortality rates by enabling prompt hospitalization, providing necessary breathing support, and implementing immunosuppressive treatments.[35]

This retrospective study only included patients receiving contingent treatment, which was a limitation of the study. This may have resulted in the designation of EOSS stage 2 as opposed to stage 3 for some patients. Several pragmatic studies have been conducted to assess the utility of the EOSS based on registries and databases. However, it is worth noting that qualitative approximations have been utilized to establish the various EOSS stages.[36,37] To validate EOSS's utility in such clinical contexts, prospective studies that provide a more precision determination of EOSS are required.

In conclusion, our findings indicate that COVID-19 patients who are hospitalized and have a BMI falling within the overweight or obese range may experience unfavorable outcomes if they have comorbidities related to obesity, as determined by EOSS stage. This

**Table 4.** Univariate, age and gender-adjusted, and comorbidities-adjusted logistic regression analysis of the outcomes among patients with different stages of Edmonton Obesity Staging System versus normal weight.

| Outcomes | Models | Normal | EOSS Stages | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Stage 1 | | Stage 2 | | Stage 3 | |
| | | OR (95% CI) | OR (95% CI) | *P* | OR (95% CI) | *P* | OR (95% CI) | *P* |
| Pneumonia | Univariate | Reference | 12.3 (3.4-44.1) | **<.001** | 5.8 (1.9-18.2) | **.003** | 40.4 (11.1-146.1) | **<.001** |
| | Model a | | 12.5 (3.3-46.5) | **<.001** | 5.0 (1.6-16.0) | **.007** | 38.8 (10.2-147.9) | **<.001** |
| | Model b | | 12.3 (3.3-45.9) | **<.001** | 5.3 (1.7-17.0) | **.005** | 52.6 (12.8-215.1) | **<.001** |
| | Model c | | 8.2 (1.7-38.4) | **.008** | 4.3 (1.1-17.1) | **.036** | - | - |
| Cytokine release syndrome | Univariate | Reference | 4.2 (1.1-16.7) | **.041** | 2.4 (0.8-7.7) | .127 | 32.1 (9.8-105.1) | **<.001** |
| | Model a | | 4.0 (1.0-16.0) | .054 | 2.1 (0.6-6.6) | .219 | 31.4 (9.2-106.8) | **<.001** |
| | Model b | | 3.8 (1.0-15.6) | .061 | 2.2 (.7-7.0) | .191 | 43.9 (11.7-164.2) | **<.001** |
| | Model c | | 1.8 (.3-9.8) | .446 | 1.5 (.4-5.9) | .589 | - | - |
| COVID Severity | Univariate | Reference | 9.9 (2.9-32.6) | **<.001** | 5.3 (1.9-15.0) | **.002** | 27.3 (8.3-89.5) | **<.001** |
| | Model a | | 10.1 (2.9-34.9) | **<.001** | 4.5 (1.6-13.1) | **.005** | 28.0 (8.0-97.6) | **<.001** |
| | Model b | | 9.9 (2.8-34.5) | **<.001** | 4.8 (1.7-14.0) | **.004** | 38.7 (10.3-97.7) | **<.001** |
| | Model c | | 6.1 (1.4-26.1) | **.014** | 3.8 (1.1-11.9) | **.033** | - | - |

Data is presented as odds ratio and 95% confidence interval of clinical outcomes including pneumonia (yes vs no), cytokine release syndrome (yes vs no), and COVID-19 severity (severe vs moderate) in patients with different stages of EOSS taking 'normal weight' as reference. Multivariate logistic regression analysis was done to produce the table. Model 'a', 'b', and 'c' represents adjustment with age, gender, and comorbidities (hypertension, diabetes, dyslipidemia, and asthma), respectively.

**Table 5.** Univariate, age, and gender-adjusted, and co-morbidities-adjusted logistic regression analysis of the outcomes among patients with different states of BMI versus normal weight.

| Outcomes | Models | BMI categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | Normal | Overweight | | Obesity class 1 | | Obesity classes 2 and 3 | |
| | | | OR (95% CI) | *P* | OR (95% CI) | *P* | OR (95% CI) | *p* |
| Pneumonia | Univariate | Reference | 6.77 (2.2-21.1) | .001 | 13.06 (3.9-42.9) | <.001 | 32.37 (7.8-133.8) | <.001 |
| | Model a | | 6.32 (1.9-20.1) | .002 | 10.74 (3.2-36.3) | <.001 | 31.37 (7.1-137.5) | <.001 |
| | Model b | | 6.36 (2.0-20.2) | .002 | 12.89 (3.7-44.7) | <.001 | 32.19 (7.3-142.8) | <.001 |
| | Model c | | 3.53 (.8-14.4) | .074 | 10.38 (2.2-49.6) | .003 | 13.79 (1.7-111.6) | .014 |
| Cytokine RS | Univariate | Reference | 2.99 (.9-9.2) | .056 | 7.78 (2.5-24.1) | <.001 | 17.76 (4.6-68.4) | <.001 |
| | Model a | | 2.74 (.9-8.5) | .081 | 6.68 (2.1-21.1) | .001 | 15.74 (3.9-62.4) | <.001 |
| | Model b | | 2.75 (.9-8.5) | .081 | 7.69 (2.4-24.7) | .001 | 15.70 (3.9-62.6) | <.001 |
| | Model c | | 0.91 (.2-4.2) | .91 | 3.09 (.6-16.5) | .187 | 5.43 (.7-41.1) | .101 |
| COVID Severity | Univariate | Reference | 5.77 (2.0-16.3) | .001 | 9.87 (3.3-29.7) | <.001 | 29.61 (7.9-111.3) | <.001 |
| | Model a | | 5.37 (1.8-15.5) | .002 | 8.34 (2.7-25.9) | <.001 | 28.57 (7.1-114.8) | <.001 |
| | Model b | | 5.43 (1.9-15.7) | .002 | 9.98 (3.1-31.9) | <.001 | 28.89 (7.1-117.3) | <.001 |
| | Model c | | 3.11 (.9-11.1) | .081 | 7.31 (1.7-30.9) | .007 | 10.81 (1.6-72.4) | .014 |

Note: Data was presented as odds ratio and 95% confidence interval of clinical outcomes including pneumonia (yes vs No), Cytokine RS (yes vs no) and COVID severity (severe vs moderate) in patients with different states of BMI, taking 'normal weight' as reference. Multivariate logistic regression analysis was done to produce the table. Model 'a', 'b' and 'c' represent adjustment with age, gender and comorbidities (hypertension, diabetes, dyslipidemia and asthma). *P*<.05 was considered as statistically significant.

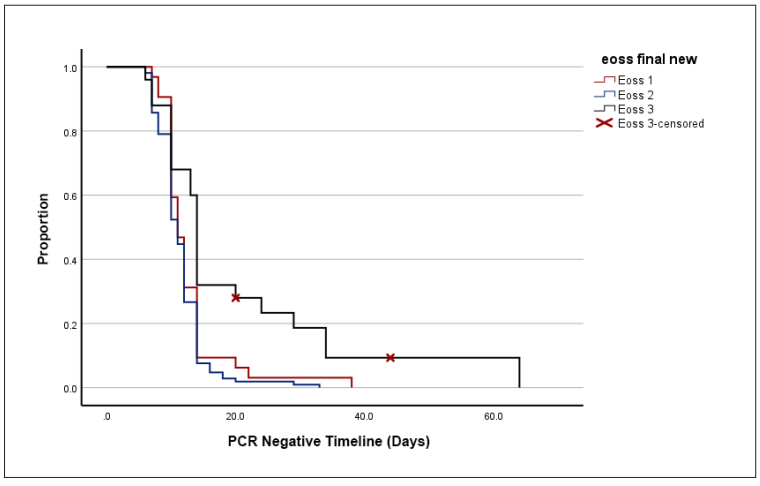


**Figure 1.** Association between time length to virus clearance for different EOSS stages.

suggests that the health status of obese patients is a more precise indicator of the progression of COVID-19 during hospitalization than BMI alone. Further investigation is imperative to gain a more comprehensive understanding of this correlation, with the ultimate goal of providing hospitalized individuals who are obese with precise prognostic guidance.

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**Appendix 1.** Edmonton Obesity Staging System (EOSS) definition.

| Stage | Conceptual description (Sharma and Kushner 2009) | Modified study definition* |
|---|---|---|
| 0 | No apparent obesity-related risk factors (e.g., BP, serum lipids, fasting glucose, etc., within normal range), no physical symptoms, no psychopathology, no functional limitations and (or) impairment of well-being. | This stage was not examined as those patients were not available in the current study data. |
| 1 | Presence of obesity-related subclinical risk factors (e.g., borderline hypertension, impaired fasting glucose, elevated liver enzymes, etc.)<br>Mild physical symptoms (e.g., dyspnea on moderate exertion, occasional aches and pains, fatigue, etc.)<br>Mild functional limitations<br>Mild psychopathology and (or)<br>Mild impairment of well being | Patients with systolic blood pressure between 130 and 139 mmHg and diastolic blood pressure between 80 and 90 mmHg, Non-fasting glucose between 140 to 199 mg/dL |
| 2 | Presence of established obesity-related chronic disease (e.g., hypertension, type 2 diabetes, sleep apnea, osteoarthritis, reflux disease, polycystic ovary syndrome, anxiety disorder, etc.)<br>Moderate limitations in activities of daily living and (or)<br>Moderate impairment of well being | Previous diagnosis and/or pharmacological treatment for T2DM, HTN, DL and/or Blood pressure ≥140/90 mmHg, fasting glucose ≥126 mg/dL, non-fasting glucose ≥200 mg/dL, total cholesterol >200 mg/dL, triglycerides >150 mg/dL and elevated liver enzymes. |
| 3 | Established end-organ damage (e.g., myocardial infarction, heart failure, diabetic complications, incapacitating osteoarthritis, etc.)<br>Significant psychopathology.<br>Significant functional limitations and (or)<br>Significant impairment of well being | Patients who reported the previous CVD, chronic renal or liver disease/failure and/or clinical evidence of CVD, serum creatinine >1.12 mg/dL, and liver enzymes ≥2-fold the UNL |
| 4 | Severe (potentially end-stage) disabilities from obesity-related chronic diseases.<br>Severe disabling psychopathology<br>Severe functional limitations and (or)<br>Severe impairment of well-being. | This stage was not examined as these factors were not available in the current study data. |