The impact of obesity on hospitalized patients with COVID-19 infection in the Eastern Province of Saudi Arabia

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ABSTRACT
This study aimed to assess the association of obesity with the severity and outcome of COVID-19 infection. A retrospective observational study was performed from March to September 2020 in Saudi Arabia. Baseline and laboratory data were collected from the inpatient health record system. The cohort was divided into three groups based on body mass index. Following this, the severity and outcome of COVID-19 disease were analyzed among the three groups. Of the 502 COVID-19 cases included, 244 (48.5%) were obese. Obesity was significantly associated with severe (33.5%) or critical (28%) COVID-19 infection (P<0.001) and a higher need for ICU admission (35.8%, P=0.034). Multivariate analysis showed that overweight/obesity was an independent risk factor of severe (P<0.001) as well as critical COVID-19 infection (P=0.026, respectively) and a predictor of a higher risk of ICU admission (P=0.012). Class I obesity was associated with severe-critical COVID-19 disease (33.6%, P=0.042) compared to other obesity classes. Obesity is an independent risk factor for severe-critical COVID-19 infection and a higher risk of ICU admission. Clinicians should give special attention to such populations and prioritize vaccination programs to improve outcomes.

KEYWORDS: body mass index, outcome, obesity, mortality, severity, COVID-19.

INTRODUCTION
In March 2020, the World Health Organization (WHO) announced coronavirus disease (COVID-19) as a global pandemic [1]. As of writing this report, it had affected approximately 269 million cases worldwide, with a total mortality rate of 5 million cases [2]. Saudi Arabia is highly affected by this pandemic. As of December 2021, there are 550,000 affected cases, with a total mortality rate of 8800 cases [3].

The course of COVID-19 infection varies widely among patients [4], and some patients present a higher risk of serious illness and bad outcomes [5]. Those include older patients or patients with co-morbidities like chronic kidney disease (CKD), hypertension (HTN), cardiac diseases, and diabetes mellitus (DM) [6].

Several observational studies showed that obese and/or overweight people have more adverse outcomes of COVID-19 disease [7, 8]. For example, Simonnet et al. studied the relationship between obesity and COVID-19 infection severity and found that a higher percentage of critical care admissions were among patients with obesity [9]. Similarly, Cai et al. reported that patients with obesity had a higher odds ratio (2.42) of developing severe pneumonia [10]. The prevalence of obesity is high in both genders in the Saudi population [11]. In fact, obesity increases over time, with a reported prevalence of 27.6% among the Saudi population [12].

The majority of retrospective studies performed in Saudi Arabia during the same period focused on more complex outcomes such as DM [13, 14], mental health [15], and other risk factors, including vitamin D deficiency [16–18]. These studies were also concentrated in the central region.

Uncovering the association between COVID-19 infection severity and body mass index (BMI) is necessary for treatment.
However, published data on this association in Saudi Arabia and the Middle East is scarce. Therefore, the aim of the current study was to assess the impact of obesity on the outcomes and severity of hospitalized patients with COVID-19 infection in Eastern Saudi Arabia.

MATERIAL AND METHODS

This retrospective observational study was carried out in two tertiary hospitals in the Eastern Province of Saudi Arabia (King Fahd Military Medical Complex and King Fahd Hospital of the University) from March to September 2020. Inclusion criteria included all admitted patients who were ≥18 years, confirmed COVID-19 disease by SARS-COVID-19 PCR test. Exclusion criteria were pregnant women and patients with malignancy and immunodeficiency diseases. First, the cohort was divided according to patients’ BMI into three groups: (1) normal weight (BMI 20–24.9 Kg/m²), (2) overweight (BMI 25–29.9 Kg/m²), and (3) obese (BMI ≥30 Kg/m²) [13]. Then, the obese group was further divided into 3 classes: Class I (BMI 30–34.9 Kg/m²), Class II (BMI 35–39.9 Kg/m²), and Class III (BMI ≥40 Kg/m²) [19].

Data collection

Data was collected from the inpatient health record system of the two hospitals and included the following: (1) socio-demographic information (age, gender, and nationality), (2) body weight, height, and calculated BMI, (3) co-morbidities (DM, HTN, CKD, and cardiac diseases), (4) baseline laboratory investigations: D-dimer, erythrocyte sedimentation rate (ESR), ferritin, complete blood count (CBC), C-reactive protein (CRP), lactate dehydrogenase (LDH) and renal profile, (4) COVID-19 severity data classified according to the 2020 Saudi Ministry of Health COVID-19 Management Guidelines [20]. The following criteria were followed in the classification of the severity of COVID-19 disease:

A. Mild-moderate disease: if there is no pneumonia on chest x-ray and no oxygen requirement;
B. Severe disease: reflected by any of the followings: oxygen saturation ≤93% on room air, respiratory rate ≥30/minute, partial pressure of oxygen (PaO₂)/fraction of inspired oxygen (FiO₂) <300 or lung infiltrates >50% of the lung field within 24–48 hours and;
C. Critical disease reflected by any of the followings: altered level of consciousness, acute respiratory distress syndrome (ARDS), sepsis, multi-organ failure, or risk factors of cytokine storm syndrome if there are one or more of the followings: Ferritin >600 ug/L at presentation and LDH>250 U/L or high D-Dimer >1 mcg/ml.

The outcomes of COVID-19 infection were determined by the need for intensive care unit (ICU) admission, mechanical ventilation, length of hospital stay, and mortality. Then, the outcomes and severity of COVID-19 disease were compared and analyzed between the three study groups. After that, we compared the outcomes and severity of COVID-19 between the three classes of obesity.

Statistical Analysis

Data were analyzed using the IBM SPSS version 24 software. The distribution of the categorical variables was summarized using percentages, and continuous variables were presented using median and interquartile range (IQR). Associations between categorical variables were assessed using Fisher exact test or Chi-square test. Multiple regression was used to assess the predictors of COVID-19 infection outcomes and severity. For all the analyses, the significance level was set at 5% (≤0.05).

RESULTS

Demographic characteristics and co-morbidities

In total, 502 confirmed COVID-19 cases were included in the study. There were 176 (35.1%) females and 326 (64.9%) males. The majority, 369 (73.7%), were Saudis. The majority of patients, 217 (43.2%), were aged between 41–60 years, followed by 151 patients (30.1%) between 61–80 years, 111 (22.1%) cases between 20–40 years, 14 (2.8%) cases were above >80 years and 9 (1.8 %) cases were < 20 years.

Out of 502 cases, 244 (48.6%) were obese, 149 (29.7%) were overweight, and 109 (21.8%) had normal weight. A total of 202 (40.2%) had severe COVID-19 disease, 148 (29.5%) mild-moderate disease, and 152 (30.3%) were critical cases. The most prevalent co-morbidities were DM (39.9%) followed by hypertension (38.9%), CKD (24.5%), and cardiac disease (18.76%) (Table 1).

Comparison of laboratory findings between the study groups

The study results displayed that blood urea nitrogen (BUN), lymphocyte, and ferritin were significantly higher in patients with diabetes mellitus; HTN – hypertension; BMI – body mass index; CKD – chronic kidney disease.
Obesity (P<0.05). In addition, CRP, LDH, D-dimer, ESR, and neutrophils were higher in patients with obesity, but they did not reach statistical significance. All other parameters were statistically similar in the three groups (Table 2).

**Association between co-morbidities and the outcomes and severity of COVID-19 infection**

Univariate analysis indicated a significant association between cardiac disease and critical COVID-19 infection (P=0.021). However, there was no association between the severity of COVID-19 pneumonia with gender, age, and other co-morbidities (Table 3).

**Table 2. Laboratory findings among COVID-19 groups according to BMI.**

| Laboratory parameter | Normal range | Normal weight | Median (IQR) | Overweight | Obese | P-values |
|----------------------|--------------|---------------|--------------|------------|--------|----------|
| WBCs                 | (4.0–10.0 k/ul) | 7.3 (3.8–11.6) | 8.9 (4.4–14.9) | 9.8 (5.4–14.7) | 0.052 |
| Hgb Females          | (12.0–16.0 g/dl) | 12.8 (11.9–14) | 13 (12.7–14.7) | 13.7 (11.9–14.4) | 0.244 |
| Hgb Males            | (13.0–18.0 g/dl) | 13.2 (11.9–14) | 13 (12.7–14.7) | 13.7 (11.9–14.4) | 0.244 |
| Platelets            | (140–450) | 196.5 (149.5–252) | 190 (158–247) | 212 (155–260) | 0.858 |
| Neutrophil           | (2.0–7.5 k/ul) | 4.6 (2.4–8.3) | 7 (3–10.9) | 7.1 (3.4–11.8) | 0.053 |
| Lymphocyte           | (1.0–5.0 k/ul) | 1.1 (0.8–2) | 1 (0.7–1.3) | 1.3 (0.9–1.7) | <0.001 |
| BUN                  | (7–26 mg/dl) | 12.6 (9–18.9) | 13.7 (10–19) | 15 (11–23) | 0.003 |
| Creatinine           | (0.6–1.2 mg/dl) | 0.9 (0.7–1.2) | 1 (0.8–1.2) | 1 (0.8–1.3) | 0.066 |
| Na                   | (136–146 mEq/L) | 135 (131–137.5) | 135 (133–139) | 136 (132–137) | 0.271 |
| K                    | (3.5–5.1 mEq/L) | 4 (3.8–4.5) | 4.2 (3.6–4.5) | 4.2 (3.8–4.5) | 0.062 |
| CO₂                  | (20–31 mEq/L) | 23 (21–26) | 23 (21–26) | 24 (20–26) | 0.766 |
| LDH                  | (81–234 U/L) | 376 (297.5–515) | 376 (281–608) | 411 (304–570) | 0.557 |
| ESR                  | (0–20 mm/hour) | 48.5 (26.5–75) | 52 (39–72) | 52 (32–67) | 0.811 |
| CRP                  | (0.1–0.5 mg/dl) | 8.3 (3.6–17.7) | 8.9 (4.1–18.8) | 10.2 (5.2–18.4) | 0.535 |
| D-Dimer              | ≤0.5 µg/mL | 1 (0.5–3.4) | 0.8 (0.5–1.4) | 1.1 (0.6–1.7) | 0.986 |
| Ferritin             | (21.81–274.66 ng/ml) | 325 (131–741) | 548 (214–1311.1) | 591 (270–1154) | 0.003 |

WBCs – white blood cells; Hgb – Hemoglobin; Na – Sodium; K – Potassium; Cl – chloride; CO₂ – Carbon dioxide; LDH – Lactate dehydrogenase; ESR – Erythrocyte sedimentation rate; CRP – C-reactive protein; bold – Significant value.

**Table 3. Association between severity of COVID-19 infection with co-morbidities, age, and gender.**

| Variable          | Mild-Moderate | Severe | Critical | P-value |
|-------------------|---------------|--------|----------|---------|
| Gender            |               |        |          |         |
| Male              | 93 (28.5%)    | 129 (39.6%) | 104 (31.9%) | 0.53 |
| Female            | 55 (30.7%)    | 73 (40.8%) | 48 (26.8%) |         |
| Age               |               |        |          |         |
| <20               | 3 (33.3%)     | 5 (55.6%) | 1 (11.1%) | 0.21   |
| 20–40             | 36 (32.4%)    | 51 (45.9%) | 24 (21.6%) |         |
| 41–60             | 57 (26.3%)    | 90 (41.5%) | 70 (32.3%) |         |
| 61–80             | 46 (30.5%)    | 50 (33.3%) | 55 (36.4%) |         |
| >80               | 6 (42.9%)     | 6 (42.9%) | 2 (14.3%) |         |
| Co-morbidities    |               |        |          |         |
| Diabetes mellitus | 54 (27%)      | 92 (46%) | 54 (27%) | 0.3     |
| Hypertension      | 51 (26.2%)    | 82 (42.1%) | 62 (31.8%) | 0.5     |
| Cardiac disease   | 27 (28.7%)    | 28 (29.8%) | 41 (41.3%) | 0.021   |
| Chronic kidney    | 31 (25.4%)    | 47 (38.5%) | 44 (36.1%) | 0.3     |

Univariate analysis test. Bold – Significant value.

Association between obesity and the outcomes and severity of COVID-19 infection

Univariate analysis (Table 4, Figure 1) revealed that obesity was significantly associated with critical (27.9%) or severe (53.3%) COVID-19 infection (P<0.001). Examining the association of body weight based on BMI with different severity classes of COVID-19 infection revealed that mild-moderate disease was associated with normal weight (51.4%; P<0.0001).

However, obesity was associated with all severe class criteria (P<0.0001) and cytokine storm syndrome with high LDH and ferritin from the critical class criteria (P=0.003) (Table 4, Figure 1). However, other outcome variables were not significant
among the three groups (Table 4, Figure 1). In multivariate analysis (Table 5), higher BMI levels (including overweight and obese groups) were an independent risk factor for both severe (OR 2.4; P<0.001) and critical (OR 1.4; P=0.026) COVID-19 disease. Looking at the association between outcome and BMI, our results revealed that a higher BMI was associated with a greater need for ICU admission (35.8%, P=0.034). Furthermore, multivariate analysis showed that higher BMI was an independent risk factor for ICU admission (OR 1.0; P=0.012) (Table 5).

Comparison of age, gender, and different classes of obesity on the outcomes and severity of COVID-19 infection

Older age >40 years was associated with a higher risk of ICU admission, death, and longer hospitalization (P<0.05). We also found that male gender was associated with longer hospitalization (P=0.034). In addition, HTN was significantly associated with a higher requirement for ICU admission (OR 0.59; P=0.035), mechanical ventilation (OR 0.48; P=0.018) and death (OR 0.32; P=0.007).

Table 4. Association between outcomes and severity of COVID-19 infection according to BMI.

| Severity | The study groups based on BMI | P-Values |
|----------|-----------------------------|---------|
|          | Normal weight | Overweight | Obese |
| Mild-moderate | 45 (41.3%) | 57 (38.3%) | 46 (18.8%) | <0.001 |
| Severe  | 29 (26.6%) | 43 (28.9%) | 130 (53.3%) |
| Critical | 35 (32.1%) | 49 (32.9%) | 68 (27.9%) |

Severity criteria

| Severity criteria | Normal weight | Overweight | Obese |
|------------------|---------------|------------|-------|
| No oxygen requirement and no pneumonia on chest x-ray | 56 (51.4%) | 64 (42.9%) | 28 (11.5%) |

Outcome

| Outcome | Normal weight | Overweight | Obese |
|---------|---------------|------------|-------|
| Hospital stay Median (IQR) (days) | 7 (3–11) | 8 (4–14) | 7 (4–12) |
| ICU Admission n (%) | 24 (22) | 50 (33.6) | 87 (35.8%) |
| Mechanical ventilation n (%) | 15 (13.8%) | 26 (17.4%) | 43 (17.7%) |
| Death n (%) | 9 (8.3%) | 11 (7.4%) | 22 (9.1%) |

Univariate analysis test. BMI – Body mass index; PaO₂ – Partial pressure of oxygen; FiO₂ – Fraction of inspired oxygen; LDH – lactate dehydrogenase; IQR – Interquartile range; ICU – Intensive care unit; N – number; % – percentage; bold – Significant value.
talization time (P=0.02). In addition, obesity (class I) was associated with a higher risk of severe-critical COVID-19 infection (33.3%, P=0.042). However, there was no difference between obesity classes in the outcome variables, including the need for mechanical ventilation, ICU admission, length of hospitalization, or death (Table 6).

**DISCUSSION**

Our study shows the following key results. First, out of 502 COVID-19 patients, a significant proportion was either obese (48.6%) or overweight (29.7%), constituting at least 70% of our cohort, which indicates a high risk of hospitalization among overweight/obese patients. Second, higher BMI (including being overweight and obese) was associated with severe-critical COVID-19 in univariate analysis, and the multivariate analysis confirmed it as an independent risk factor for severe-critical COVID-19 disease. Third, obesity and/or being overweight are independent risk factors for ICU admission. Next, obesity (class I) was associated with a higher risk of severe-critical COVID-19 infection in comparison with other obesity classes. However, this result is difficult to interpret in our study since most of our obese group had class I obesity. In addition, male gender and older age group >40 years in the obese group were associated with worse outcomes. Moreover, obesity was associated with increased levels of lymphocytes, BUN, and ferritin. Finally, we found that older age, male gender, CKD, and HTN were associated with a bad prognosis of COVID-19 disease.

Our study is in line with previous reports showing a significant association between higher BMI and hospitalization time, more severe COVID-19 disease, and worse outcomes, primarily

| Variable   | Severe (OR [95% CI]) | Critical (OR [95% CI]) | *Hospital stay | ICU admission (OR [95% CI]) | Mechanical ventilation (OR [95% CI]) | Death (OR [95% CI]) |
|------------|-----------------------|------------------------|----------------|-----------------------------|--------------------------------------|---------------------|
| Age        | 0.8 (0.5–1.1)         | 1.03 (0.7–1.5)         | 1.72 (1.3–2.27) | <0.001                      | 2.07 (0.4–10.7)                      | 1.63 (0.8–2.9)      |
| Gender     | 1.1 (0.7–1.6)         | 1.02 (0.8–1.2)         | 2.11 (1.37–3.25) | 0.001                       | 2.12 (0.5–11.7)                      | 1.530 (0.9–2.6)     |
| DM         | 1.4 (0.8–2.3)         | 0.6 (0.3–1.1)          | 1.31 (0.84–2.04) | 0.235                       | 1.184 (0.5–2.6)                      | 1.239 (0.7–2.2)     |
| HTN        | 1.3 (0.7–2.2)         | 1.01 (0.6–1.7)         | 0.85 (0.53–1.37) | 0.514                       | 0.59 (0.4–1.6)                       | 0.48 (0.3–1)        |
| Cardiac disease | 0.6 (0.3–1.3)     | 1.2 (0.6–2.3)          | 0.63 (0.35–1.12) | 0.118                       | 1.287 (0.7–2.2)                      | 0.410 (0.4–1.6)     |
| CKD        | 1.3 (0.7–2.3)         | 1.9 (1.3–3.5)          | 2 (1.25–3.2)    | 0.004                       | 1.079 (0.4–2.8)                      | 0.764 (0.4–2.6)     |
| *BMI       | 2.4 (1.8–3.2)         | 1.4 (1–2)              | 1.01 (0.98–1.04) | 0.582                       | 1 (0.2–2.4)                         | 0.012 (0.2–1.4)     |

Multivariate analysis test. OR–Odds ratio; CI–Confidence Interval; DM–Diabetes mellitus; HTN–Hypertension; BMI–Body mass index; CKD–Chronic kidney disease. *Hospital stay: we used a cutoff of 7 days correlated with the mean hospital stay of COVID-19 disease patients in previous studies [43]. Significant values are shown in bold.
Multiple mechanisms could explain the severe COVID-19 disease in obese individuals. First, obesity has been linked to disruptions in lymphoid tissue integrity and leukocyte development [36], indicating a greater risk of hospitalization among obese patients similar to our findings [29]. In addition, patients with obesity had a higher risk of pneumonia and ARDS [28]. Gao et al. found that higher BMI is associated with a 3-fold increased risk of severe COVID-19 pneumonia in addition to a 12% increase in the risk of severe COVID-19 infection with each 1 unit increase in BMI ≥30 kg/m² [31]. Furthermore, a meta-analysis of 46 studies conducted by Cai et al. involving 625,000 COVID-19 patients found that patients with obesity had a significantly increased risk of death (OR 1.72), mechanical ventilation (OR 1.66), ICU admission (OR 2.25) and mortality (OR 1.61) [30]. Similarly, Rottoli et al. reported a higher risk of ICU admission and respiratory failure at BMI 30-34.9 kg/m² with an increased risk of death at BMI ≥35 kg/m² [27]. Moreover, a large retrospective cohort review analysis that included 770 COVID-19 infected patients from New York concluded that around 35% of obese patients appeared to have a greater risk of ICU admission than normal-weight patients [26]. Simonnet et al. reported that almost half (47.5%) of the COVID-19 patients who were admitted to ICU had BMIs of ≥30 kg/m² [9]. Another study found a linear increase in the risk of severe COVID-19 disease at a BMI ≥23 kg/m², leading to hospital admission, ICU admission, and death [31].

Table 6. The effect of gender, age, and obesity classes on the outcomes and severity of COVID-19 infection.

| Variable         | Severe-Critical | *Hospital Stay | ICU Admission | Mechanical ventilation | Death |
|------------------|-----------------|---------------|---------------|------------------------|-------|
| **Age**          |                 |               |               |                        |       |
| ≤40 years (n=56) | 48 (85.7%)      | 19 (35.2%)    | 12 (21.4%)    | 5 (8.9%)               | 1 (1.8%) |
| >40 years (n=188)| 150 (79.8%)     | 96 (51.1%)    | 75 (39.9%)    | 38 (20.2%)             | 21 (11.2%) |
| **P-Value**      | 0.35            | 0.03          | 0.01          | 0.050                  | 0.03  |
| **Gender**       |                 |               |               |                        |       |
| Male (n=146)     | 118 (80.8%)     | 77 (52.7%)    | 56 (38.4%)    | 27 (18.5%)             | 13 (8.9%) |
| Female (n=98)    | 80 (81.6%)      | 38 (39.2%)    | 31 (31.6%)    | 16 (16.3%)             | 9 (9.2%)  |
| **P-Value**      | 0.96            | 0.02          | 0.265         | 0.63                   | 0.713 |
| **Obesity class**|                 |               |               |                        |       |
| Class 1 (BMI: 30–34.9 kg/m²) | 45 (33.3%) | 62 (45.9%) | 49 (35.6%) | 25 (18.5%) | 12 (8.9%) |
| Class 2 (BMI: 35–39.9 kg/m²) | 11 (19%)   | 29 (50%)     | 21 (36.2%)   | 13 (22.4%)             | 8 (13.8%) |
| Class 3 (≥40 kg/m²) | 12 (23.5%)  | 24 (47.1%)   | 17 (33.3%)   | 5 (9.8%)               | 2 (3.9%)  |
| **P-Value**      | 0.042           | 0.865         | 0.9           | 0.207                  | 0.202 |

*Hospital stay: we used a cutoff of 7 days correlated with the mean hospital stay of COVID-19 disease patients in previous studies [43]. Bold – Significant value.
the generalizability of our findings. Second, the present study was retrospective which could result in bias.

CONCLUSION

A greater percentage of hospitalized COVID-19 patients are either overweight or obese. In addition, obesity is an independent risk factor for severe-critical COVID-19 infection and a predictor of the need for ICU admission. As a result, clinicians should give special attention to such populations and prioritize vaccination programs to improve their outcomes.

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Conflict of interest

The authors declare no conflict of interest.

Ethical approval

This study was approved by the local Ethics Board in the two hospitals (King Fahd Military Medical Complex, IRB-2020-01-246 and King Fahd Hospital of the University, AFHER-IRB-2021-010).

Consent to participate

Written informed consent was taken from all patients.

Authorship

MA is the corresponding author and was in charge of the manuscript concept and manuscript revision and submission. DA, RA, SA, AALQ, FA, and WA contributed to the methodology and wrote the original draft. AALW, SALQ, AALZ, AALS, MAJW, TA, ZA, MZ, NA, and AALH contributed to data collection and curation. BG, FZ, AALHW, and NA contributed to data analysis.

REFERENCES

1. Coronavirus Disease (COVID-19) Situation Reports. Available from: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports.
2. WHO Coronavirus (COVID-19): Dashboard. Available from: https://covid19.who.int.
3. Saudi Arabia: WHO Coronavirus Disease (COVID-19) Dashboard With Vaccination Data. Available from: https://covid19.who.int.
4. Guan WJ, Ni ZY, Hu Y, Liang WH, et al. Clinical Characteristics of Coronavirus Disease 2019 in China. J Emerg Med. 2020; 58(2):170-20. doi: 10.1016/j.jemermed.2020.04.001.
5. Huang C, Wang Y, Li X, Ren L, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. The Lancet. 2020;395(10223):497-506. doi: 10.1016/S0140-6736(20)30183-5.
6. de Almeida-Pinto B, Duhalij PM, Zaglenew I, et al. Severity and mortality of COVID-19 in patients with diabetes, hypertension and cardiovascular disease: a meta-analysis. Diabetol Metab Syndr. 2020 Aug 31;12:64. doi: 10.1186/s41366-020-0602-y.
7. Dietz W, Santos-Burgoa C. Obesity and its Implications for COVID-19 Mortality. Obesity (Silver Spring). 2020 Jun;8(7):1200-1204. doi: 10.1002/oby.22859.
8. Sanchis-Gomar F, Lavie CJ, Mehra MR, Henry BM, Lippi G. Obesity and Outcomes in COVID-19: When an Epidemic and Pandemic Collide. Mayo Clin Proc. 2020; 95(7):1443-1453. doi: 10.1016/j.mayocp.2020.05.006.
9. Simonnet A, Chatboum M, Piaissy J, Raverdy V, et al. High Prevalence of Obesity in Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) Requiring Invasive Mechanical Ventilation. Obesity. 2020; 20(7):1195-1199. doi: 10.1002/oby.22831.
10. Cai Q, Chen F, Wang T, Luo F, et al. Obesity and COVID-19 Severity in a Designated Hospital in Shenzhen, China. Diabetes Care. 2020; 43(7): 1392-1396. doi: 10.2337/dci20-0576.
11. Albaker W, El-Ashker S, Baraka MA, El-Tanahi N, et al. Adiposity and Cardiometabolic Risk Assessment Among University Students in Saudi Arabia. Sci Prog. 2021; 104(1):36504192195352. doi: 10.1177/00368042195352.
12. Al-Qatami AM. Prevalence and Predictors of Obesity and Overweight among Adults Visiting Primary Care Settings in the Southwestern Region, Saudi Arabia. Biomed Res Int. 2019; 5:2019-070357. doi: 10.1155/2019/070357.
13. Sheshah A, Sabico S, Albhak RM, Sultan AA, et al. Prevalence of diabetes, management and outcomes among Covid-19 adult patients admitted in a specialized tertiary hospital in Riyadh, Saudi Arabia. Diabetes Res Clin Pract. 2021; 172:103581. doi: 10.1016/j.diabres.2020.103581.
14. Alguwaihes AM, Al-Sofiine ME, Megdad M, Albadar SS, et al. Diabetes and COVID-19 among hospitalized patients in Saudi Arabia: a single-centre retrospective study. Cardiaco Diabetol. 2020; 9(1):205. doi: 10.1046/j.1229-3233.2002.01184-4.
15. Alfawaz HA, Wani K, Aljumah AA, Alfisii D, et al. Psychological well-being during COVID-19 lockdown: Insights from a Saudi State University’s Academic Community. J King Saud Univ Sci. 2021; 33:101262. doi: 10.1016/j.jksus.2021.101262.
16. Alguwaihes AM, Sabico S, Hasanrato R, Al-Sofiine ME, et al. Severe vitamin D deficiency is not related to SARS-CoV-2 infection but may increase mortality risk in hospitalized adults: a retrospective case-control study in an Arab Gulf country. Aging Clin Exp Res. 2021; 33(5):1415-1422. doi: 10.1007/s40520-021-01310-1.
17. Al-Dughri NM, Amer OE, Abstabli NH, Alissi DA, et al. Vitamin D status of Arab Gulf residents screened for SARS-CoV-2 and its association with COVID-19 infection: a multi-centre case-control study. J Transal Med. 2021; 19(1):166. doi: 10.1186/s12976-021-02083-x.
18. Alkhajaji D, Al Arjan R, Albaker W, Al Elq A, et al. The Impact of Vitamin D Level on the Severity and Outcome of Hospitalized Patients with COVID-19 Disease. Int J Gen Med. 2022; 15:334-332. doi: 10.2147/IJGM.S361699.
19. Weir CB, Jan A. BMI Classification Percentile And Cut Off Points. 2021. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2022.
20. Saudi MoH Protocol for Patients Suspected of/Confirmed with COVID-19. Saudi Ministry of Health.
21. Yu W, Roldi KE, Yang S, Jia F. Impact on obesity on COVID-19 patients. J Diabetes Complications. 2021; 35(5). doi: 10.1016/j.jdiacomp.2020.107817.
22. Lighter J, Phillips M, Hochman S, Sterling GD, et al. Obesity in Patients Younger Than 60 Years Is a Risk Factor for COVID-19 Hospital Admission. Clin Infect Dis. 2020; 71(13):996-997. doi: 10.1093/cid/ciaa145.
23. Bastini S, Petrone C, Napoli N, Russo E, et al. Comparative analysi highlights increased visceral adiposity associated with critical illness in-covid-19. Diabetes Care 2020; 43(10). doi: 10.2337/dc20-1333.
24. Suleymen G, Fadel RA, Maltehe KM, Hammond G, et al. Clinical Characteristics and Mortality Associated With Coronavirus Disease 2019 in a Series of Patients in Metropolitan Detroit. JAMA Netw Open. 2020 Jun 1;3(6):e202270. doi: 10.1001/jamanetworkopen.2020.12270.
25. Kalligeros M, Shebahdi F, Myfona AK, Benitez G, et al. Association of obesity with disease severity among Patients with Coronavirus Disease 2019 (COVID-19) Obesity. Silver Spring, 2020; 8(7):1200-1204. doi: 10.1007/s12925-020-00585-6.
26. Melehan S, Elbehrawy A, Aljahadi A, Hussain N, et al. The prevalence of obesity in hospitalized COVID-19 patients at King Abdullah Medical City, Makkah, Saudi Arabia. BMJ Open Diabetes Research and Care. 2021; 9(5):1579-1582. doi: 10.24911/ BJMDC.51-1624726139.
27. Gao M, Permas C, Astbury N, Hipple-Cox J, et al. Associations between body-mass index and COVID-19 severity in 6.9 million people in England: a prospective, community-based, cohort study. Lancet Diabetes Endocrinol. 2021; 9(5):350-359. https://doi.org/10.1016/S2213-8477(21)00089-5.
28. Cai Z, Yang Y, and Zhang J. Obesity is associated with severe disease and mortality in patients with coronavirus disease 2019 (COVID-19): a meta-analysis. BMC Public Health. 2021; 21:1505 https://doi.org/10.1186/s12889-021-11546-6.
29. Gao F, Zheng K, Wang XB, Sun QF, et al. Obesity Is a Risk Factor for Greater COVID-19 Severity. Diabetes Care. 2020; 43(7):272-274. doi: 10.2337/dci20-0682.
30. Andersen CJ, Murphy KE, Fernandez ML. Impact of Obesity and Metabolic Syndrome on Immunity. Adv Nutr. 2016 Jan 15;7(1):66-75. doi: 10.3945/ AJN.115.012007.1392-1396. doi: 10.2337/dci20-0576.
36. Huang JF, Wang XB, Zheng KI, Liu WY, et al. Letter to the Editor: Obesity hypoventilation syndrome and severe COVID-19. Metabolism. 2020; 108:154249. doi: 10.1016/j.metabol.2020.154249.

37. Tham KW, Lee PC, Lim CH. Weight Management in Obstructive Sleep Apnea. Medical and Surgical Options. Sleep Med Clin. 2019; 14(1):143-153. doi: 10.1016/j.smjc.2018.10.002.

38. Busetto L, Bettini S, Fabris R, Serra R, et al. Obesity and COVID-19: An Italian Snapshot. Obesity (Silver Spring). 2020; 28(9):1600-1605. doi: 10.1002/oby.22918.

39. Shea MK, Booth SL, Gundberg CM, Peterson JW, et al. Adulthood obesity is positively associated with adipose tissue concentrations of vitamin K and inversely associated with circulating indicators of vitamin K status in men and women. J Nutr. 2010; 140(5):1029-34. doi: 10.3945/jn.109.118380.

40. Pasquarelli-do-Nascimento G, Braz-de-Melo HA, Faria SS, Santos I de O, et al. Hypercoagulopathy and Adipose Tissue Exacerbated Inflammation May Explain Higher Mortality in COVID-19 Patients With Obesity. Front Endocrinol (Lausanne). 2020; 11:530. doi: 10.3389/fendo.2020.00530.

41. Alesi MC, Bastelica D, Morange P, Berthet B, et al. Plasminogen activator inhibitor 1, transforming growth factor-beta1, and BMI are closely associated in human adipose tissue during morbid obesity. Diabetes. 2000; 49(8):1374-80. doi: 10.2337/diabetes.49.8.1374.

42. Skurk T, Hauner H. Obesity and impaired fibrinolysis: role of adipose production of plasminogen activator inhibitor-1. Int J Obes Relat Metab Disord. 2004; 28(11):1357-64. doi: 10.1038/sj.ijo.0802778.

43. Gheblawi M, Wang K, Viveiros A, Nguyen Q, et al. Angiotensin-Converting Enzyme 2: SARS-CoV-2 Receptor and Regulator of the Renin-Angiotensin System: Celebrating the 20th Anniversary of the Discovery of ACE2. Circ Res. 2020; 126(10):1436-1474. doi: 10.1161/CIRCRESAHA.120.317015.

44. Chen L, Li X, Chen M, Feng Y, Xiong G. The ACE2 expression in human heart indicates new potential mechanism of heart injury among patients infected with SARS-CoV-2. Cardiovase Res. 2020; 116(6):1097-1100. doi: 10.1093/cvr/cvaa078.

45. Liu Z, Long F, Yang Y, Chen X, et al. Serum ferritin as an independent risk factor for severity in COVID-19 patients. J Infect. 2020; 81(4):647-679. doi: 10.1016/j.jinf.2020.06.053.

46. Bettini S, Buca G, Senisi G, Dal Pei C, et al. Higher Levels of C-Reactive Protein and Ferritin in Patients with Overweight and Obesity and SARS-CoV-2-Related Pneumonia. Obes Facts. 2021;14(5):543-549. doi: 10.1159/000517851.

47. Oyelade T, Alghthani J, Canciani G. Prognosis of COVID-19 in Patients with Liver and Kidney Diseases: An Early Systematic Review and Meta-Analysis. J Trop Med Inf Dis. 2020; 5(2):90. doi: 10.3390/tropicalmed5020080.

48. Khan A, Althunayyan S, Alsufayan Y, Alotaibi R, et al. Risk factors associated with worse outcomes in COVID-19: a retrospective study in Saudi Arabia. East Mediterr Health J. 2020; 26(11):1371-1390. doi: 10.26719/emhj.20.130. PMID: 3326105.