Review Article

Viral respiratory infection in people with obesity – A review

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Abstract. This review article focused on a statistical analysis of the obesity population's viral infection rate and compared the effects from different viral respiratory infections, such as abnormal immune responses and hyperglycemia in the population with obesity. Obesity has become more prevalent in developed countries while still less in developing countries. People with obesity have higher adipose fat accumulation underneath the organ membrane and in-between tissues, which can lead to abnormal organ function and respiratory difficulties. Respiratory problems can exist in people with obesity that usually related to hypertension and dyslipidemia. Meanwhile, obesity downregulates many immune and metabolic responses in the body. Viruses like H1N1, SARS-CoV, and SARS-CoV-2 have pathological damages in the lung shared in common, in which a higher severity was observed in people with obesity. The review was done by an online article search from PubMed, Google Scholar, and NEMJ database to allocate potential case studies and review articles of our keyword criteria. The initial article search layout 206 articles related to obesity, respiratory, and virus in human studies carried out from 2000 to 2020. Further analysis has shown that 15 articles pointed out a clear relationship between obesity and viral infection. Influenza, MERS, and SARS coronaviruses reported a significantly higher infection rate in the population with obesity condition. However, there were inconsistent results regarding the relationship between obesity and pneumonia, in which pneumonia was observed in most viral respiratory infections. Comparing pathological evidence from obesity and SARS viral infections, both share in common on hyperglycemia and increase of ACE engagement, whether it is to increase blood pressure or increase virus entry. Obesity condition itself makes consequent treatments even more difficult. In suggestion, there is a need to conduct further extensive clinical studies on the people with obesity that are COVID-19 positive.

Keywords: Influenza, obesity, respiratory, SARS, virus

Introduction

In 2016, the Center for Disease Control and Prevention (CDC) reported more than 39.8% of adults in the U.S. to have an obesity problem [1]. In addition, people with obesity are highly correlated with cardiovascular disease, Type-II diabetes, and metabolic syndrome [2]. Metabolism is highly related to the quantity of energy consumed and how much the body required [3]. When the body's metabolism function is impaired, individuals may have a higher risk of getting chronic diseases due to leukocyte distribution problems and increase the production of leptin hormone that triggers abnormal innate and adaptive immune responses [4]. Therefore, an abnormal increase in immune responses promotes inflammation and sclerosis of cells from bacterial and viral infections by promoting immune cell production [4]. As for severe viral infections in the respiratory tract, higher body weight profiles have led to a higher risk of systemic failure and further require a mechanical ventilator to survive [5].

Metabolic syndrome (MetS) occurs when obesity disrupts the functions of metabolic tissues, such as adipose tissue, liver, and pancreas [3]. As the oxidative stress and dysfunction of the metabolic tissue progress, lymphoid tissues were also altered by the abnormal cytokine production and further cause problems in leukocyte distribution that can affect immune surveillance. This disruption in the immune system will re-occur in a cycle and eventually leads to chronic diseases such as Type II diabetes and vasoconstrictions [3]. Metabolism must be in balance; otherwise, the body will induce abnormal adaptive and innate immunity, which leads to pro-inflammation and cause systemic failures that are likely to get external infections.

Leptin acts as the crucial hormone that controls the metabolism of energy source into lipids and cytokine production in the immune system [4]. As in people with obesity, leptin functions were resistive to be controlled by brain signals and continue making lipids, which increase the

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feeling of starvation, upregulate food consumption, and eventually lead to hyperglycemia [4]. The overproduction of fatty acids was stored in adipocytes and distributed around the lung, heart, and other cardiovascular organs. Furthermore, higher lipid content in the lungs and bronchioles occupy the lung chamber, which further restricts the respiratory volume [6]. Besides, people with obesity may show signs of hard breathing before the actual viral infection due to their systemic oxygen volume requirement is higher than healthy people. The change in the lung environment affects the viral pathogenesis and immune response, which makes people with obesity problem prone to more extensive viral spreads [7].

Due to the reduction of immune surveillance in the human body, the respiratory tract as the first line of the immune barrier gets the most immediate symptoms after infection [8]. The range of symptoms includes coughing, sore throat, fever, hard breathing, and even diarrhea. Furthermore, patients with obesity have a slower response to fight viral infection and weak recovery from the disease. In the study from Melo L. et al. [9], individuals with obesity show reduced lung volume compared to individuals with normal weight. Since there is a restriction in respiratory volume, individuals with obesity show symptoms listed above. According to a recent study by Green et al. [10], people with obesity have less of a response to the flu vaccine. This issue is due to changes in the metabolic profile of T cells that impairs the activation and function of adaptive immunity [10].

With chronic illnesses, such as cardiovascular disease, respiratory difficulties, and heart disorders, individuals with obesity need specific health guidelines to prevent them from getting severe bacterial and viral infections. In addition, Frontline physicians and nurses can rely on the medical information of the patient's weight profile to categorize the risk severity and perform the most effective treatment for patients attend for health care with symptoms shown. During the H1N1 pandemic in 2009, obesity was an independent risk factor for disease severity [11]. However, obesity did change the individual's interferon (IFN) response, which then causes a lower response rate when infection of the virus enters the human body. Therefore, people with obesity shows the potential risk of respiratory viral infection due to its attenuation in IFN property.

For the infection of Middle East Respiratory Syndrome, the viral engaging point utilized DPP-4 on the epithelial tissues, similar functionality as SARS-CoV's engagement with ACE-2 on the epithelial cell surface [12]. When comparing SARS-CoV to SARS-CoV-2, they shared similar receptor binding motifs and bind to ACE-2, which is release in high amount by the obesity's effect [13]. Both DPP-4 and ACE-2 increased in amount while an individual's BMI increases, which is highly related to obesity condition [14].

Currently, the number of populations globally who tested positive on COVID-19 surpassed 3 million by May 2020 [15]. It's an ongoing global health emergency, and now, not enough information on COVID-19 infected population has a conclusive answer for the relationship between obesity and COVID-19 in each country. Besides, if we look at the data of hospitalized patients, most of the reported data suggest people with obesity might be at higher risk of getting severe symptoms and requires mechanical ventilators to survive [16, 17].

The review was performed and discussed the potential relationship between individuals with obesity and respiratory issues from different viral infections. Further analysis focused on checking for the prevalence of severe viral respiratory diseases and immune system alterations from the people with obesity that were diagnosed and hospitalized with COVID-19, MERS, or H1N1 viral infections.

Materials and Methods

Purpose of review

The review was conducted to compare different viruses' effects from statistical view and pathological evidence in people with obesity to provide potential disease information for clinical studies to deal with the unknowns of COVID-19. The goal of the review was to find relevant pathological evidence that speaks to a definite cause of higher infection rates for COVID-19 in people with obesity. In addition, people with obesity might have a higher risk of immune dysfunction and potentially get infected with severe respiratory diseases. Furthermore, successfully categorizing risks can save future diagnosis time and prescribe more accurate treatment of the illness

Inclusion and exclusion criteria

Inclusion criteria: 1) The study used keyword combinations of obesity, respiratory, and virus to conduct an extensive search for articles in online databases. 2) Selected studies are human studies carried out between the years 2000 to 2020. 3) Include reviews on other factors for infection of COVID-19. 4) Selected articles in the English language only.

Exclusion criteria: 1) Exclude articles that are not in the time range. 2) Exclude articles of non-human studies. 3) Exclude articles that are not in the keyword of selection.

Search methodology

The search for articles must meet our specific criteria, including using MeSH and searching on PubMed to allocate correlated articles to our goal correctly. By inputting obesity, respiratory, and virus into MeSH, the initial result provides 206 articles within our search criteria.

Search strategy

Further analysis of article choice was performed to pick out 15 articles with firm supporting details to our goal. Our search has narrow down to focus on the effects of viral infection in population with or without obesity conditions and compare the immune responses between people that are healthy and people with obesity. As for COVID-19, the reported data collected from hospitalized patients were also analyzed in this review and provide crucial information for future studies.

TABLE 1

RELATIONSHIP OF OBESITY TO VIRAL RESPIRATORY INFECTION IN EACH STUDY

Title of Article	Type of Study	Types of Viral Infection	Relationship Between obesity and viral infection
Investigating obesity as a risk factor for influenza like illness during the 2009 H1N1 influenza pandemic using the Health Survey for England	Case Study	H1N1 Influenza	No Significant Relationship
Obesity as a risk factor for severe influenza-like illness. Influenza Other Respir Viruses	Case Study	H1N1 Influenza	Little to Moderate Relationship
Obesity and respiratory infections: Does excess adiposity weigh down host defense?	Review Article	H1N1 Influenza	Some articles reviewed show independent risk but some articles show high influences between obesity and influenza [18]
Underweight, overweight, and obesity as independent risk factors for hospitalization in adults and children from influenza and other respiratory viruses.	Case Study	Influenza and other Respiratory Viruses	Adults that have obesity with H1N1 got a six-fold increase in chance of hospitalization over H3N2 and Influenza Type B [19].
Relationship between community prevalence of obesity and associated behavioral factors and community rates of influenza-related hospitalizations in the United States	Case Study	Influenza Viruses	Obesity were more likely to have high influenza related hospitalization rates [20].
Obesity Impairs the Adaptive Immune Response to Influenza Virus	Review Article	Influenza Virus (Seasonal)	Obesity impairs cellular response and further induce higher risk of viral infection [10].
Impact of Obesity on Influenza A Virus Pathogenesis, Immune Response, and Evolution	Case Study	Influenza Type A Virus	Obesity generate lean environment for viral infection [7].
An international perspective on hospitalized patients with viral community-acquired pneumonia	Case Study	Influenza and Viral Pneumonia	Obesity and need for invasive ventilation represent independent risk factors for viral community acquired pneumonia [21].
Epidemiology of severe influenza outcomes among adult patients with obesity in Detroit, Michigan, 2011	Case Study	H1N1 Influenza	Patients with obesity were more likely to require hospital admission as well as a lengthy hospital stay (>7 days) [22].
Obesity and pro-inflammatory mediators are associated with acute kidney injury in patients with A/H1N1 influenza and acute respiratory distress syndrome.	Case Study	H1N1 Influenza	High levels of C-peptide and BMI were associated with the development of acute respiratory distress syndrome patients due to A/H1N1 infection [23].
Factors associated with hospitalization and critical illness among 4,103 patients with COVID-19 disease in New York City.	Case Study	SARS-CoV-2	6.2% of the 1,999 hospitalized COVID-19 patients have BMI over 40 [24].
Hospitalization rates and characteristics of patients hospitalized with laboratory-confirmed coronavirus disease 2019 — COVID-NET, 14 states	Case Study	SARS-CoV-2	Over 48% of the hospitalized COVID-19 patients have obesity issues [25].
High prevalence of obesity in severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) requiring invasive mechanical ventilation.	Case Study	SARS-CoV-2	In the collection of 124 patients, obesity (BMI >30 kg/m2) and severe obesity (BMI >35 kg/m2) were present in 47.6% and 28.2% of the total cases respectively.
SARS-CoV-2 infection and obesity: Common inflammatory and metabolic aspects	Review Article	SARS-CoV-2	SARS-CoV-2 share the same metabolic pathway with obesity and engage ACE as a primary player.

TABLE 1 Continued

Two important controversial risk factors in SARS-CoV-2 infection: Obesity and smoking	Review Article	SARS-CoV-2	Angiotensinogen II are highly produced from obesity condition, which ACE is upregulated. SARS-CoV-2 can utilize the excess ACE-2 to enter host cells.

Results

According to the comparison shown in Table 1, people with obesity were highly studied in influenza virus infection and SARS viral infection. When comparing H1N1's viral respiratory infection to SARS infections, most of the SARS infection showed patients with obesity are in a chronic state of inflammation that leads to decreased and compromised immunity. However, according to some studies, mixed results were discovered. Some findings show little to no relationship between obesity and H1N1 infection, while some show twice or higher prevalence in patients with obesity. In addition, from some early findings in the COVID-19 patients' profile, close to half of the hospitalized patients have BMI over 30, which is a factor that indicates obesity. In addition, findings from SARS-CoV-2 and the ACE-2 engagement gave a potential connection between obesity and viral infection.

Statistical importance

According to Center of Disease Control and Prevention (CDC), the classification of obesity is as follow: Class I obesity (BMI $\geq$ 30-34.9 kg/m2); class II obesity (BMI $\geq$ 35-39.9 kg/m2); class III obesity (BMI $\geq$ 40kg/m^2) [26]. This classification of data is used to determine the state of obesity to further organized data of viral infection rates. As for the result, H1N1 infection reported 50% of the hospitalized patients to have BMI $\geq$ 30 kg/m^2 [22]; SARS-CoV-2 disease reported 68.5% of the hospitalized patients to have an average BMI of 31.1 kg/m^2 [27], while data from New York University Hospital reported 6.2% of the hospitalized patients to have BMI $\geq$ 40kg/m^2 [24].

Discussion

Viral infection in respiratory tract

Respiratory systems are lined with epithelial cells composed of adipocytes and columnar epithelial cells that form a lining that surveillance the area [28]. In a viral respiratory infection, the upper and mild respiratory tract is damaged and causes severe illness like pharyngitis, rhinitis, otitis media, and sinusitis [29]. Most of the lower respiratory tract infections were associated with bacteria, respiratory syncytial virus (RSV), and influenza virus, including symptoms like pneumonia and bronchiolitis [30]. Therefore, the members of the beta coronavirus family, including MERS, SARS, and SARS-CoV-2, are more likely to cause upper and mild respiratory tract infections.

In addition, most of the pathological data collected from the recent COVID-19 outbreak reported 80% of the symptoms in infected patients restricted to upper respiratory tract infections, such as fever, fatigue, cough, sore throat, runny nose, and sneezing [31]. Moreover, H1N1 infections reported more cases of pneumonia and bronchiolitis during the 2009 pandemic [32]. As shown in Figure 1, when the respiratory tract is abnormally lined with fatty acids on the epithelial cells, the more likely the receptors for virus were express and allow viral entry.

Effects in the body caused by obesity

Obesity is a severe overweight health disorder that can lead to cardiovascular diseases, respiratory diseases, stroke, diabetes, and cancers. Individuals with obesity issues usually correlate with excessive accumulation of body fat, which further causes cardiovascular diseases, diabetes, musculoskeletal disorders, and cancers [33]. According to a recent report from Brethauer S. [34], most of the patients with obesity have Type II diabetes and cardiovascular diseases as the most common disorders. Furthermore, the classification in BMI index number shows how severe the obesity issues individuals got, which BMI number higher than 30 km/m2 accounts for obesity.

Obesity's effects started when the pancreas' production of insulin is resistive to ingested food glucose and further cause hyperglycemia in peripheral tissues. Leptin and resistin hormone increased production as a response to increasing metabolism in the body. As metabolism increases, lipid substances increase in output due to the high amount of free fatty acids. Obesity also triggers the production of angiotensinogen hormone, which is used to regulate blood constrictions and pressure. A high amount of angiotensinogen will induce the production of angiotensin-converting enzyme (ACE). ACE can convert angiotensinogen to angiotensinogen type II (AT-II) [35]. A high amount of AT-II will increase the blood pressure and further cause vasoconstrictions at the lungs, heart, and cardio-vasculatures. These issues can further cause a reduction in immune response and increase the risk of Type II diabetes [8].

Influenza effects in people with obesity

H1N1 pandemic in 2009 has caused more than 1.6 million people worldwide diagnosed with virus infection [36]. The epidemic of H1N1 has a typical infection route via the upper and lower respiratory tract as well as infecting cells in the lungs [32]. The relationship between obesity and influenza discovered from studies have different results.

Some research studies have pointed out that influenza has little to no relationship between flu-like illness in the population that have obesity [37, 38]. According to a study from Murphy R. et al. [37], the obesity factors are independent of the flu-like illness. Their research focused on 8,407 individuals in the U.K that had developed the flu-
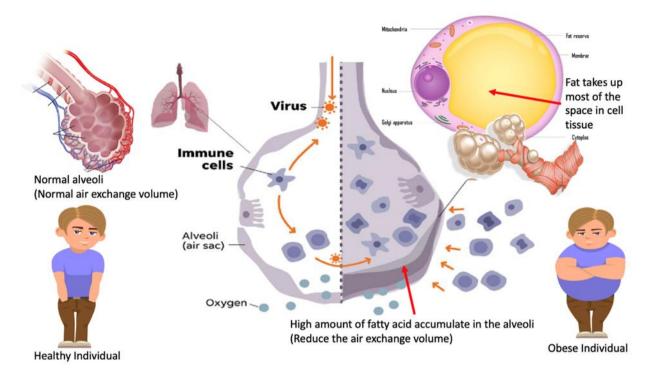
Figure 1. Respiratory function comparison between normal and obesity individual [48].

like disease from May 2009 to December of 2009. They categorized these individuals into groups of ages, BMI, and prior disorders to find out that only 12.8% of the individuals with obesity in the U.K during the pandemic period exists with flu-like illness [37]. Another study conducted by Cocoros et al. [38] pointed out that their results show little to moderate correlation between obesity and flu-like illness during the H1N1 outbreak. Their discussion explained the reason why not getting a significant substantial relationship between obesity and flu-like symptoms might be due to their small sample size used in the study.

On the other hand, several studies pointed out that people with obesity poses a higher risk of getting flu-like illness as much as twice the chance when compared to healthy people. A study conducted by Green W. et al. [10] measures two different influenza seasons (2013-14 and 2014-15) and allocate 1022 participants to study their illness responses. Their results show that vaccinated people with obesity have twice the chance of getting flu-like illnesses than the people that are vaccinated and healthy. Furthermore, their findings pointed out that people with obesity have impaired CD4 T-cells for immune response, which then poses a higher risk of getting the illness. Besides, people with obesity can produce inflammatory cytokines that promote more inflammation responses.

Another study carried out by Martin E. et al. [22] used data from influenza patients admitted to Detroit Medical Center System, during the period January of 2011 to the end of March 2011, to collect medical records to access the risk of getting hospitalized for influenza infection. In the 161 patients studied, 81% had Influenza A, while more than half of the inpatients have obesity Class I to Class III [22]. Since the H1N1 influenza infection is mostly associated with lower respiratory tract infection, the relevance to COVID-19 is less suitable to compare. However, the prevalence of H1N1 viral infection in people with obesity does prove the effects of abnormal metabolism somehow disrupt the immune system.

Middle East respiratory syndrome's effects in people with obesity

Middle East Respiratory Syndrome (MERS) is caused by one of the β coronavirus family members (MERS-CoV), which induces severe respiratory diseases in human subjects. In addition, the recent COVID-19 has been reported shown using similar receptors from the upper and lower respiratory tract to enter host cells, which is also used in SARS-CoV and MERS-CoV infections [39]. However, the significant difference between MERS-CoV and SARS-CoVs are the receptor-binding motifs (RBM) in their core structure of receptor-binding domain (RBD), MERS-CoV utilized the Dipeptidyl peptidase 4 (DPP-4) while SARS-CoV and SARS-CoV-2 utilized Angiotensin-Converting Enzyme 2 (ACE-2) [13].

The adipokine, DPP-4, has been reported by studies showing that it is the docking receptor for MERS-CoV into host cells [12, 40]. In addition, DPP-4 has demonstrated a high influence on the obesity condition in humans [14]. The study by Sell et al. [14], shows a higher release of DPP-4 from the visceral and subcutaneous adipose tissues from insulin-resistant patients and women higher than men. As the amount of lipid being metabolized increased, the amount of DPP-4 accumulate in the adipose tissue increases. DPP-4 is responsible for keeping the balance between glucose metabolism DPP-4 is the receptor for MERS-CoV entering host cells, expressed highly in epithelial cells at the
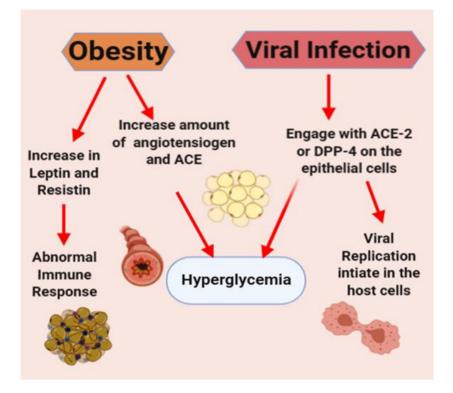
Figure 2. Diagram showing the relationship between obesity and coronavirus viral infection.

upper and lower respiratory tract, which makes people get MERS infected [40]. MERS infection is pathologically related to obesity in that people with obesity express more DPP-4 in their adipose tissue. The overexpressed DPP-4 at the human upper and lower respiratory tract can further on, causing these people with obesity conditions more likely to get MERS infected [41].

Severe acute respiratory syndrome's effects in people with obesity

According to a study reported by Yang J. et al. [42], the Severe Acute Respiratory Syndrome (SARS) can induce transient islets damage and cause acute insulin-dependent diabetes mellitus. In addition, the SARS-CoV virus was found to use ACE-2 protein as the entry receptor to enter host cells. In further examination, the SARS-CoV and the SARS-CoV-2 shared similar receptor-binding motifs, ACE-2. ACE-2 is highly expressed in epithelial cells that surround the upper and lower respiratory tract.

Due to pancreatic islets expressed more ACE-2 protein than the exocrine cells, SARS-CoV can cause more damage to the pancreatic islets. Then, the damage to islet cells can cause hyperglycemia to occur temporally, in which hyperglycemia is commonly observed in people with obesity [42]. Furthermore, people with obesity have an even higher risk of SARS-CoV infection due to enlarged hyperglycemia from both the islets and leptin hormone malfunction [42]. Pre-existing symptoms in people with obesity can become worse when SARS-CoV binds to ACE-2 in the pancreatic islet, which can induce a larger hyperglycemia event, and lead to severe diabetes mellitus condition. In Figure 2, the relationship of obesity and

coronaviruses infection, such as MERS, SARS, and COVID-19, have been sketched out with direct links to increase the chance consequent damage in host cells.

COVID-19's effects in people with obesity

The function of epithelial cells' angiotensin-converting enzyme 2 (ACE-2)

This particular enzyme attached to the outer membrane of human cells, especially epithelial cells located at the mucosal organs such as salivary glands, lung, heart, esophagus, kidney, bladder, and ileum [43]. ACE-2 has a specific receptor-binding domain (RBD) that allows SARS-CoV-2 to bind and dock on host cells. When SARS-CoV-2's spike proteins attached to the RBD on ACE-2, viral RNA is released from the viral envelope and enters human cells for replication. The process allows SARS-CoV-2 to rapidly produce and increase its chance of survival on the human host to overcome the immune system's attack. There are two waves of inflammatory response when SARS-CoV-2 binds ACE-2.

The primary inflammatory response increases host immune attack and increases cytokine production. This change in immune response will then cause viral cell apoptosis. In the secondary response, the neutralizing antibodies are formed and trigger a macrophagic mechanism. However, these neutralizing antibodies are not optimized to kill the SARS-CoV-2, which later on might cause leakage of virus and induce symptoms such as coughing and lung injury [44]. Currently, there is no definite route of immunological suppression, as many subtypes of SARS-CoV-2 have been discovered and

manifest human cells in a slightly different pathway.

Current knowledge of COVID-19's relationship with obesity

As of June 2020, the COVID-19 disease has no cure and vaccine yet. The chances of getting the infection, especially in people with obesity, might be higher than other groups of the population. Physicians and health authorities are eager to find a health and safety guideline to help prevent further transmission and reduce the number of cases infected with SARS-CoV-2. SARS-CoV-2 from COVID-19 utilizes its S-glycoprotein to bind tightly to human angiotensin-converting enzyme 2 (ACE-2) receptors on adipose tissue, specifically in the respiratory tract. In the recent findings from Jia X. et al. [45], the ACE-2 receptors are highly expressed in the lung adipose tissue, which shows more immediate respiratory symptoms such as coughing and restricted breathing after the infection of SARS-CoV-2. In their further findings, Jia X. et al. [45] also pointed out that since the population with obesity has higher adipose fat contents in their lung tissue, more ACE-2 receptors are expressed to allow more SARS-CoV-2 to get attached.

On April 8, 2020, the Center for Disease Control and Prevention (CDC) [25] has published an early report of multiple hospitals' non-peer reviewed data collection on hospitalized COVID-19 patients. Within the data collected, more than 48.3% of the COVID-19 patients have obesity. In the COVID-19 patients with obesity conditions, age from 18 to 40 years old account for more than 59%, which is higher than the total percentage of the population with obesity in the U.S. [25]. Therefore, a clear indication of obesity increases the risk of severe respiratory illness can acknowledge from the statistics; however, we still need more samples to cross-reference data to get a conclusive answer to the relationship between obesity and COVID-19. Meanwhile, another study from doctors at New York University Grossman School of Medicine collected patients' profiles and medical records that are COVID-19 positive. In the study, Petrilli C. et al. [24] pointed out that in the 4,103 COVID-19 positive patients, 1,999 were hospitalized, and 6.2% of the hospitalized patients have a BMI over 40, which is count as obesity. The goal is to find out who is at risk for hospitalized after the SARS-CoV-2 infection and to help clinicians to assess the severity to give the best treatment immediately.

According to the study from Simonnet et al. [27], the clinical data collected from 124 patients for SARS-CoV-2 infection reported that 85 patients (68.6%) required invasive mechanical ventilation (IMV). The BMI data collected was higher than in the 39 patients (31.4%) who did not require IMV: 31.1 (27.3-37.5) kg/m^2 vs 27 (25.3-30.8) kg/m^2, respectively (p<0.001, t-test) [27].

Furthermore, using the medical data collected from recent hospitalized COVID-19 patients to conduct cross-referencing researches and clinical studies to find the specific cause of COVID-19 in the population with obesity. Declined in immune surveillance or T-cells response might be the cause. Clinical evidence does show ACE-2 engagement are highly related to the upregulation of ACE in obesity condition. Obesity upregulates ACE to overcome a high amount of angiotensinogen, which virus-like SARS-CoV-2 can use ACE to dock to host cells to induce viral replication. Furthermore, it is suggested to conduct an extensive study of immune factors to clarify the cause of hyperglycemia from SARS-CoV-2.

Conclusion

The current pandemic of COVID-19 has been reported to infect over 2.2 million people globally, 150 thousand of which resulted in death [46]. In discovery, countries that have a high percentage of populations with obesity have clinical data reporting a higher prevalence of COVID-19 infection and higher chances of getting hospitalized with a mechanical ventilator required. Studies on previous H1N1 viral respiratory pandemic, some clues on immune system downregulation, and distress could be a similar cause in the COVID-19 cases. However, the H1N1 influenza virus is not as closely related to SARS-CoV-2.

The receptors ACE-2 in SARS coronavirus and DPP-4 in MERS-CoV were released in high amounts from the obesity condition when looking at viral infections of MERS and SARS coronaviruses. There was pathological evidence in terms of showing a positive relationship between abnormal hormone responses in obesity affecting the receptors that bind viruses, which further increase the rate of respiratory infections. However, the symptoms of pneumonia from virus infection have been reported controversial when relating to obesity, as pneumonia can be caused by various inflammatory responses [47].

In further suggestions, the data collected from a current pandemic could be used for retro-studies in the future time to find out specific causes, like how does SARS-CoV-2 cause hyperglycemia, and the relationship between the patients with obesity's abnormal immune responses to SARS-CoV-2.

Conflict of Interest

The authors declare no conflict of interest.

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