World Medical and Health Policy

COVID-19 and Morbid Obesity: Associations and Consequences for Policy and Practice

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While the impact of obesity on chronic disease has been widely examined, there has been less research regarding the influence of obesity on infectious diseases, particularly respiratory diseases. This exploratory research uses the currently available data on COVID-19 cases and mortality, along with estimates of the morbidly obese populations in the United States by county, to examine the association between morbid obesity and deaths from COVID-19 and to identify potential coincident spatial clusters of morbid obesity and COVID-19 deaths. Results indicate a statistically significant positive correlation between population-adjusted COVID-19 deaths and cases and the estimated population with a body mass index ≥ 40. Clustering analyses show there is a predominant similarity in the distribution of COVID-19 deaths and obesity. Our findings suggest it is critical to include an awareness of obesity when developing infectious disease control measures and point to a greater need to focus resources toward obesity education and policy initiatives.

KEY WORDS: obesity, COVID-19, body mass index, spatial clustering

Introduction and Background

The primary goals of this study and commentary are to perform an initial exploratory analysis of the association of morbid obesity with negative outcomes of COVID-19 infections and if such an association is found to then argue for the importance of recognizing obesity as an independent predictor of such negative outcomes; information that could help shape policy and practice. We begin with a review of the literature surrounding obesity, and its association with infectious respiratory illnesses. Subsequently, Spearman's rank correlation and spatial cluster analysis procedures are used to explore potential relationships among morbid obesity and both incident cases of COVID-19 and deaths caused by COVID-19. We present the results demonstrating associations, and discuss the policy and practice implications.

The Challenge of Obesity

Overnutrition and obesity have created significant health problems locally, nationally, and globally. Worldwide, overweight and obesity have affected 1.9 billion adults. Overweight and obesity are linked to more deaths worldwide than underweight. Globally there are more people who are obese than underweight—this is the

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case in every region except parts of sub-Saharan Africa and Asia (World Health Organization, 2020). As of 2016, a staggering 39.7 percent of the United States' population is obese and 71.3 percent is either obese or overweight (Center for Disease Control and Prevention and National Center for Health Statistics, 2019). Since the introduction of processed foods in the United States in the 1970s and their increased prevalence in the developing world by the 1990s, diets have transitioned from nutrient-rich to mostly energy-dense foods. This greater consumption of high-calorie foods coupled with decreasing energy expenditure has led to significant increases in overweight and obesity, particularly in the United States (Pawloski, Thurman, Curtin, & Ruchiwit, 2012; Popkin, 2001).

Within the United States, obesity is highly associated with socioeconomic status; there are higher obesity rates in areas of low socioeconomic status (Drewnowski, Rehm, & Solet, 2007; Pan American Health Organization and World Health Organization, 2000). The majority of research on obesity within the United States has also shown significant associations between obesity and chronic diseases including heart disease, diabetes, liver disease, hypertension, cancers, and even Alzheimer's disease. It has been estimated that the cost of obesity in 2014 was $149.4 billion at the national level (Kim & Basu, 2016).

While the impact of obesity on chronic disease has been widely examined, there has been less research regarding the impact of obesity on infectious diseases. This is primarily the case as most disease concerns in the United States are based on chronic disease burdens, unlike the dual burden of disease placed on many low- and middle-income nations (Popkin & Gordon-Larsen, 2004). A study done in England and Scotland recently showed that in those with elevated central obesity there is an association with mortality from infectious diseases in general (Hamer, O'Donovan, & Stamatakis, 2019). Further, Torres, Martins, Faria, and Maioli (2018) have noted that obesity is associated with an increased inflammation that can impair the body's immune responses to infections from bacteria, viruses, and parasites.

COVID-19 is a respiratory virus that is thought to have originated from zoonotic transmission, most likely in China. The current global pandemic of COVID-19, which is highly contagious with presumed high mortality rates, has dramatically increased the need to understand the association between obesity and negative health outcomes from respiratory disease, particularly death. Early reports, which are mostly anecdotal, have shown an increased risk of developing severe complications and mortality with morbid obesity (World Obesity Federation, n.d.). Morbid obesity is defined as having a body mass index (BMI) greater than or equal to 40, and has been clearly associated with chronic disease, health complications, and death. While recent reports reveal that comorbidities related to obesity, particularly diabetes, hypertension, and cardiovascular disease, are directly related to increased aggravation of COVID-19, there are indications that obesity itself may directly link to increasing severe symptoms and mortality of COVID-19 (Papagianni & Tziomalos, 2017; Petrilli et al., 2020). These include associations related to inflammation and pulmonary function. Further, as obesity is typically inclusive of the other related COVID-19 comorbidities, is less invasive to detect, and is frequently reported in global health population surveys, we do believe obesity can be an ideal tool to assist in predicting greater risk of COVID-19 symptoms and mortality within populations. Thus, here we explore existing morbid obesity data in the United States and the presence of COVID-19 cases and deaths to show that such analyses can be helpful in understanding risk and trends of COVID-19.

Obesity, Pulmonary Function, Inflammation, the Immune Response, and Risk for Respiratory Viruses

While the COVID-19 relationship with obesity is only beginning to be understood, we can use the influence of obesity on pulmonary function in general and risk for respiratory viruses to explore the possible impact of obesity on COVID-19. The prevalence of pulmonary problems in patients with obesity is higher than for normal-weight individuals as obesity has been found to adversely affect respiratory function (Lourenço, 1969; Rasslan et al., 2004). The primary effects of obesity on lung function stem from the mechanical impact of the accumulation of excess adipose tissue in the chest wall and abdomen, increasing intra-abdominal pressure, causing increased stiffness in the lungs thereby reducing lung volume and capacity (Salome, King, & Berend, 2013). The distribution of fat cells in the body also influences lung volumes. The tendency for men to carry fat in the trunk (abdominal obesity) and upper body further restricts respiratory mechanics, more so than in women who tend to carry weight lower in the body (Enzi et al., 1986; Mafort, Rufino, Costa, & Lopes, 2016). Increased abdominal pressure also influences gastric processes, which may inhibit lower esophageal sphincter closure and cause reflux of gastric fluid to be aspirated into the respiratory tract, potentially resulting in pneumonia (Mancuso, 2013a, 2013b).

Further, the accumulation of excess adipose tissue negatively affects the systemic immune response by contributing to a chronic state of inflammation and inhibiting host response to infection (Bulló, García-Lorda, Megias, & Salas-Salvadó, 2003; Lumeng & Saltiel, 2011; Mancuso, 2013a). Recent research has shown that increased levels of c-reactive protein (CRP) can predict more severe COVID-19 symptoms (Wang et al., 2020). CRP is a protein produced by the liver that is typically elevated when there is inflammation in the body, and typically higher in obese populations, suggesting that understanding obesity trends may help us understand where there is more risk associated with COVID-19.

Evidence of decreased pulmonary function and immune response in obese and morbidly obese patients can be observed in the increased susceptibility to pulmonary viral infections as was found in prior studies of the H1N1 influenza pandemic of 2009 (Almond, Edwards, Barclay, & Johnston, 2013; Honce & Schultz-Cherry, 2019; Kwong, Campitelli, & Rosella, 2011). Obese and morbidly obese patients exhibited greater severity of illness (Centers for Disease Control and Prevention, 2009; Vaillant, La Ruche, Tarantola, & Barboza, 2009) requiring hospitalization (Jain et al., 2009), admission into the intensive care unit (ICU; Fezeu et al., 2011; Fuhrman et al., 2011), and critical illness and death (Gill et al., 2010; Jhung et al., 2011; Morgan et al., 2010). Moreover, in the ICU setting, obese patients may require both prolonged duration of mechanical ventilation and longer hospitalization overall (Akinnusi, Pineda, & El Solh, 2008; Litinski, Owens, & Malhotra, 2013).

Recent analysis of the COVID-19 pandemic in New York City found that male, obese, hospitalized patients were more likely to require mechanical ventilation, and had increased mortality (Petrilli et al., 2020). Studies of severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), which is in the same RNA virus family as COVID-19, revealed that the disease severity of SARS-CoV-2 increased with BMI, with over 85 percent of patients with a BMI > 35 requiring intubation (Simonnet et al., 2020). In the same viral family, studies of the Middle East respiratory syndrome coronavirus (MERS-CoV), also showed that obesity increased illness severity and viral load (Al-Hameed, 2017). Not only does obesity increase an individual's risk for serious complications from respiratory viruses, but a recent study also found that obese adults shed the influenza A virus about 1.5 times longer than nonobese adults (Maier et al., 2018). This finding demonstrates a potential increase in the spreading opportunity of viral diseases.

Research Questions

From this review of the literature, we can confirm, not surprisingly, that obesity is a pervasive problem and that its association with negative health outcomes is clear, including with regard to respiratory disease. We also conclude that while there are indications that this relationship holds with COVID-19, the reports are as of yet anecdotal and limited to individual locations. In order to contribute to this literature, we present in this article a quantitative nationwide analyses at the county level of correlations between estimates of the prevalence of morbid obesity in the population and of the negative outcomes from COVID-19. Moreover, we present a spatial statistical analysis showing the level of co-location of these variables.

Toward that end, we use the currently available data on COVID-19 cases and mortality, along with estimates of the morbidly obese populations in the United States by county to examine whether obesity may be a contributing factor in rates of infection and/or death from the disease.

Our research questions are:

(1) Is there a correlation between morbid obesity and negative outcomes from COVID-19?
(2) Are spatial clusters of high values of estimates of the percent of the population with morbid obesity associated with clusters of high values of population-adjusted COVID-19 deaths?

Materials and Methods

In this section, we describe the data used to represent populations with morbid obesity, and the most recent data for cases and deaths associated with COVID-19 and briefly describe our statistical methods.

Data

Obesity Data. In order to generate estimates of the population with morbid obesity for each U.S. county we have integrated elements of the National Health and Nutrition Examination Survey (NHANES) and population data from the U.S. Bureau of the Census as of 2000. The NHANES survey is conducted by the National Center for Health Statistics at the Centers for Disease Control and Prevention and is updated continuously (Center for Disease Control and Prevention, 2020). The 1999–2006 NHANES data set consists of information collected during home interviews, and the results of health tests administered at Mobile Examination Centers. The survey used complex, multistage, stratified, and clustered samples of civilian, noninstitutionalized populations. The age range of the participants was 2 months and older, with no upper limit on age. This study limits its population to those aged 18–64. In order to support this rapid response article, we used previously generated estimates of the number of persons estimated to be morbidly obese per 100,000 population. These estimates were generated from the 2006 NHANES data; specifically the rates of obesity associated with gender and race subgroups of the population. Those rates were then applied to those subgroup populations in each county, based on the U.S. Bureau of the Census data from 2000, with the overall population rate of morbid obesity (5.9 percent in 2006) applied to all persons outside of those subgroups.

COVID-19 Data. The COVID-19 data include numbers of individuals who are confirmed positive for COVID-19 as well as the numbers of deaths from the disease. We use data provided by the *New York Times* (NYT) that includes a series of files with cumulative counts of coronavirus cases and deaths in the United States, at the state and county level, over time (*New York Times*, 2020). The NYT has compiled this time series data from state and local governments and health departments in an attempt to provide a complete record of the ongoing outbreak. The data have been updated daily since the first known cases in the United States in late January 2020. For this study, we collected the COVID-19 data as it was reported through April 22, 2020. State and county files contain FIPS codes, a standard geographic identifier, which permit us to join these data to our estimates of the population with morbid obesity.

Statistical and Spatial Statistical Analyses

We used the following methods to examine the association between morbid obesity and negative outcomes from COVID-19. Descriptive statistics are used to gain a better understanding of the nature of the data. Spearman's rank correlation coefficient was used to examine the association between increasing values of obesity indicators and cases and deaths from COVID-19. The Getis-Ord Gi* local spatial clustering statistic was applied to counties on a state-by-state basis to examine if there are any similar spatial associations between the locations where a larger percent of the population is estimated to be morbidly obese, and the locations where there are greater numbers of deaths from COVID-19 on a population-adjusted basis. This statistic indicates where observations have a high (or low) value and where their neighboring observations also have a high (or low) value. These are spatial clusters or colloquially "hot spots" and "cold spots." In the absence of any literature regarding the appropriate spatial definition of a neighborhood for either population obesity values or COVID-19 deaths, we chose contiguous counties (both edge and corner contiguity) as the means of determining an observation's neighborhood.

Results

We sequentially present the results of this exploratory analysis with descriptive statistics, results of correlations between COVID-19 cases and deaths with measures of obesity, and spatial statistical analyses indicating the spatial association between COVID-19 and obesity.

Descriptive Statistics

Descriptive statistics of the data are found in Table 1. As of April 22, 2020, there were 1,443 counties with at least one reported death from COVID-19. "BMI ≥ 40" is the estimated number of adults aged 18–64 years with a BMI greater than or equal to 40 per 100,000 population. "Cases" and "Deaths" are the numbers of COVID-19 cases and deaths per 100,000 adults aged 18–64 years, respectively. "Cases_Count" and "Deaths_Count" are the raw COVID-19 case and dealth counts. There were 861,558 cases and 39,365 deaths reported as of April 22, 2020. The data are all positively skewed, with Cases and Deaths data exhibiting a high degree of peakedness as documented by the high kurtosis values. The peaks in the Cases and Deaths data relate to counties that have experienced significant outbreaks of COVID-19; as such the data do not follow a normal distribution. Each data set was

Table 1. Descriptive Statistics of Body Mass Index (BMI) ≥ 40 and COVID-19 Values per 100,000 Adults Aged 18–64 per County

	BMI ≥ 40	Cases	Cases_Count	Deaths	Deaths_Count
Mean	4,667.73	333.83	597.06	18.05	27.28
Standard error	23.33	13.54	63.24	0.74	2.90
Median	4,310.98	182.57	79	8.80	3
Mode	4,591.74	70.59	14	1.27	1
Standard deviation	886.33	514.24	2,402.31	28.06	110.33
Range	5,418.48	5,614.15	31,554	381.54	1,763
Kurtosis	2.80	32.72	86.38	35.62	86.50
Minimum	3,580.63	4.74	1	0.48	1
Maximum	8,999.11	5,618.90	31,555	382.02	1,764
Sum	6,735,537.85	481,723.09	861,558	26,040.54	39,365
Count	1,443	1,443	1,443	1,443	1,443

assessed for normality using Shapiro–Wilk and Kolmogorov–Smirnov tests and all variables were found to significantly deviate from a normal distribution.

Correlation Analyses

The primary results from the correlations are that there are consistently positive and statistically significant correlations between COVID-19 outcomes and indicators of obesity. As the data are characterized with a nonnormal distribution and presence of relevant outliers, Spearman's rank correlation coefficient was utilized to assess the directional relationship from ranks of the data due to its robustness against outliers. Spearman's ρ was calculated for COVID-19 cases in each county per 100,000 adults aged 18–64 years and the estimated population with a BMI $\geq$ 40 per 100,000 adults ages 18–64, as well as with unadjusted case values "Cases_Count" to estimated percent population with a BMI $\geq$ 40. Similarly, the number of COVID-19 deaths per 100,000 adults ages 18-64 per county and unadjusted death values "Deaths_Count" were examined against the BMI $\geq$ 40 data set. The results are summarized in Table 2, and scatterplots of the data are presented in Figures 1–4.

In all cases these correlations were positive, indicating that a larger number of COVID-19 outcomes are associated with larger values for the morbid obesity indicators. The positive correlations may be described as "weak" in the range of 0.20–0.39 for some and "very weak" for one as defined by Evans (1996). That said, given that it is highly likely that negative outcomes from COVID-19 are the result of a complex set of social, demographic, cultural, and physiological variables, we cannot reasonably expect a very strong correlation with the obesity variable alone. However, we can interpret these results by squaring rho to find the amount of variation that a change in one variable is associated with change in the other. For the case where $\rho = 0.305$, ρ^2 is 0.093. This indicates that the prevalence of morbid obesity alone explains 9.3 percent of the variation in COVID-19 cases. There are three compelling results here: first, that the positive correlation persists with every test. Second, the significance level suggests that the probability of this relationship being the result of random chance is less than one in one hundred. And third, as a matter of practical importance, with the complex interactions that are likely to produce negative COVID-19 outcomes, any single variable that can explain more than 9 percent of the variation is worth examining further.

Table 2. Correlation Analysis of COVID-19 Cases and Deaths to Indicators of Obesity

Spearman's rank correlation analysis				
Variable 1	Variable 2	Spearman's ρ	p value	Significance Level
Cases	BMI $\geq$ 40	0.305	<.0001	0.01
Deaths	BMI $\geq$ 40	0.116	<.0001	0.01
Cases_Count	BMI $\geq$ 40	0.289	<.0001	0.01
Deaths_Count	BMI $\geq$ 40	0.281	<.0001	0.01

BMI, body mass index.

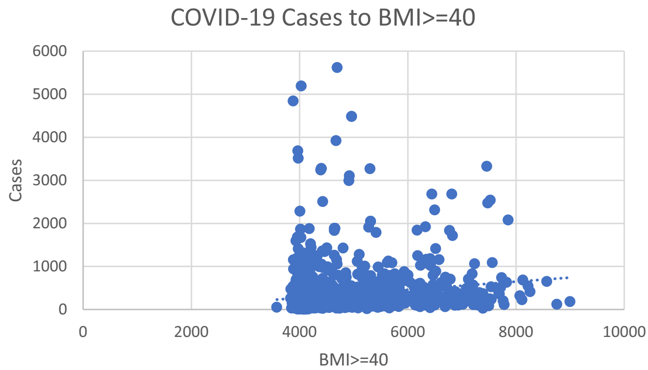

Figure 1 COVID-19 Cases to the Estimated Population With Body Mass Index (BMI) ≥ 40, per 100,000 Adults Aged 18–64.

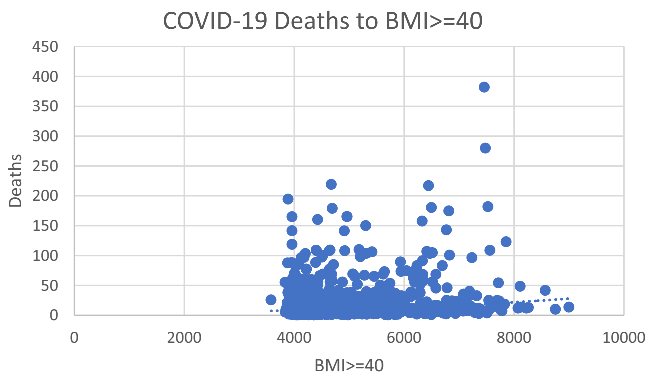

Figure 2 COVID-19 Deaths to the Estimated Population With Body Mass Index (BMI) ≥ 40, per 100,000 Adults Aged 18–64.

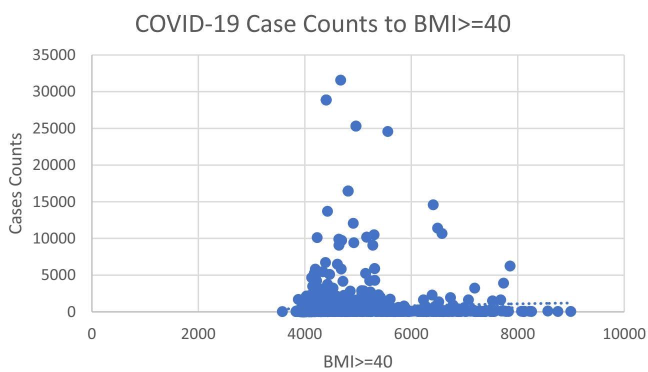

Figure 3 COVID-19 Cases Counts to the Estimated Population With Body Mass Index (BMI) ≥ 40, per 100,000 Adults Aged 18–64.

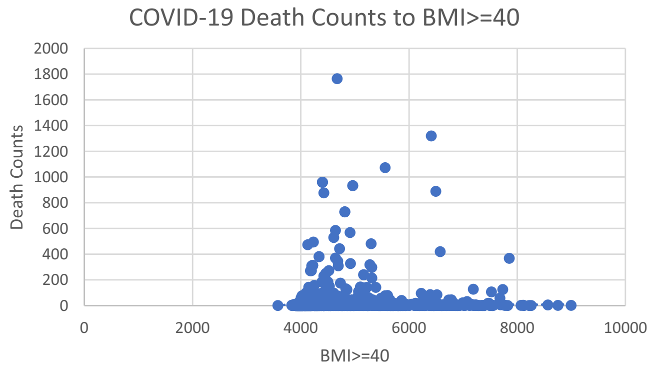

Figure 4 COVID-19 Deaths Counts to the Estimated Population With Body Mass Index (BMI) ≥ 40, per 100,000 Adults Aged 18–64.

Spatial Statistical Clustering Analysis

For the clustering analysis the variables tested were the population-adjusted estimates of the prevalence of BMI ≥ 40 (BMI%) and the number of deaths from COVID-19 per population (DEATHS_PER_POP). The Getis-Ord Gi* Local Clustering Statistic was computed for both variables and the resulting significant high-high and low-low value counties were mapped. The number of counties that showed significant Gi* values in both tests were compared. See Figures 5 and 6 for an example with the state of Illinois.

Of the 10 counties that are in statistically significant clusters of high BMI% values in Illinois, seven are also in statistically significant clusters of high DEATHS_PER_POP values. The similar comparison for Georgia (Figures 7 and 8) shows that of the 35 counties that are in statistically significant clusters of high BMI% values, 15 are also in a statistically significant clusters of high DEATHS_PER_POP values. We summarize the results from additional states in Table 2 below and comparative maps are provided in the Appendix (the legend for Figures 5–8 holds). For all 11 states tested there were 63 counties with a high-high relationship indicating that higher BMI% values are associated with higher mortality from COVID-19. Moreover, when comparing low Gi* scores for both BMI% and DEATHS_PER_POP, there were five counties—all in California—where that relationship held. There was only one case (Florida) where there were low Gi* scores for DEATHS_PER_POP and also high Gi* scores for BMI% in three counties. Conversely, in Texas two counties in the far northwest of the state (Moore County and Hartley County) had significant high Gi* DEATHS_PER_POP values (99% confidence), along with significant low Gi* BMI% values (90 percent confidence). Moore County is the location of the JBS meatpacking plant, which has experienced a significant localized outbreak of COVID-19. In summary, there were 68 counties with either a high-high or low-low relationship indicating that higher values of the percentage of population estimated to have a BMI ≥ 40 were associated with greater risk of death from COVID-19. There were only five counties with a high-low or low-high relationship that contradicted that hypothesis. This analysis also shows that

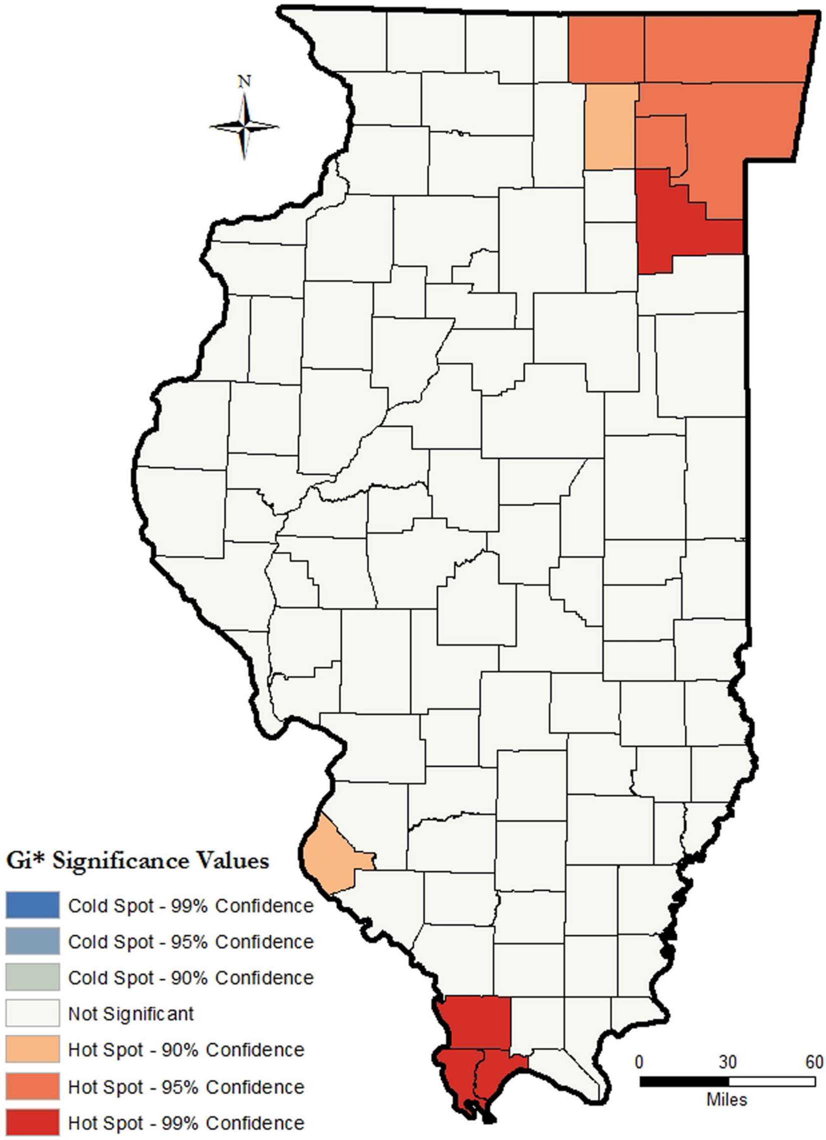

Figure 5 Illinois Clusters of Body Mass Index% values.

anomalies such as the meatpacking plant situation can be identified through this method (Table 3).

Discussion and Policy and Practice Implications

Overall, the results show that there is, in fact, a consistent, statistically significant association between morbid obesity and negative outcomes from COVID-19. While there has been anecdotal evidence of this relationship in news articles and

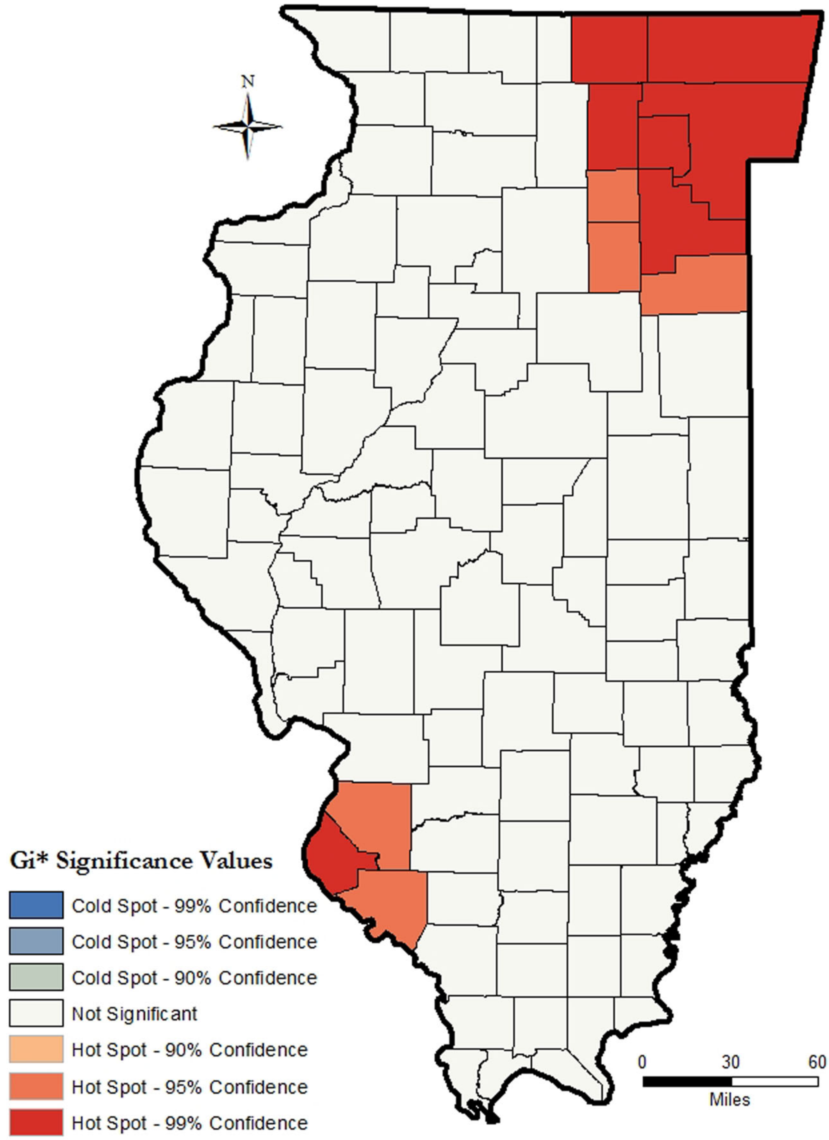

Figure 6 Illinois Clusters of DEATH_PER_POP Values.

short (nonexperimental) letters (Dietz & Santos-Burgoa, 2020) and comments (Stefan, Birkenfeld, Schulze, & Ludwig, 2020), in this study we have been able to leverage existing data to perform what we believe are among the first repeatable quantititative analyses that address this relationship. Further, as this is a time-sensitive topic, most studies so far related to obesity and COVID-19 have been conducted in China, where obesity levels are lower, and in hospital settings. These data can help to understanding trends within counties and states throughout the U.S. population where obesity rates are some of the highest in the world.

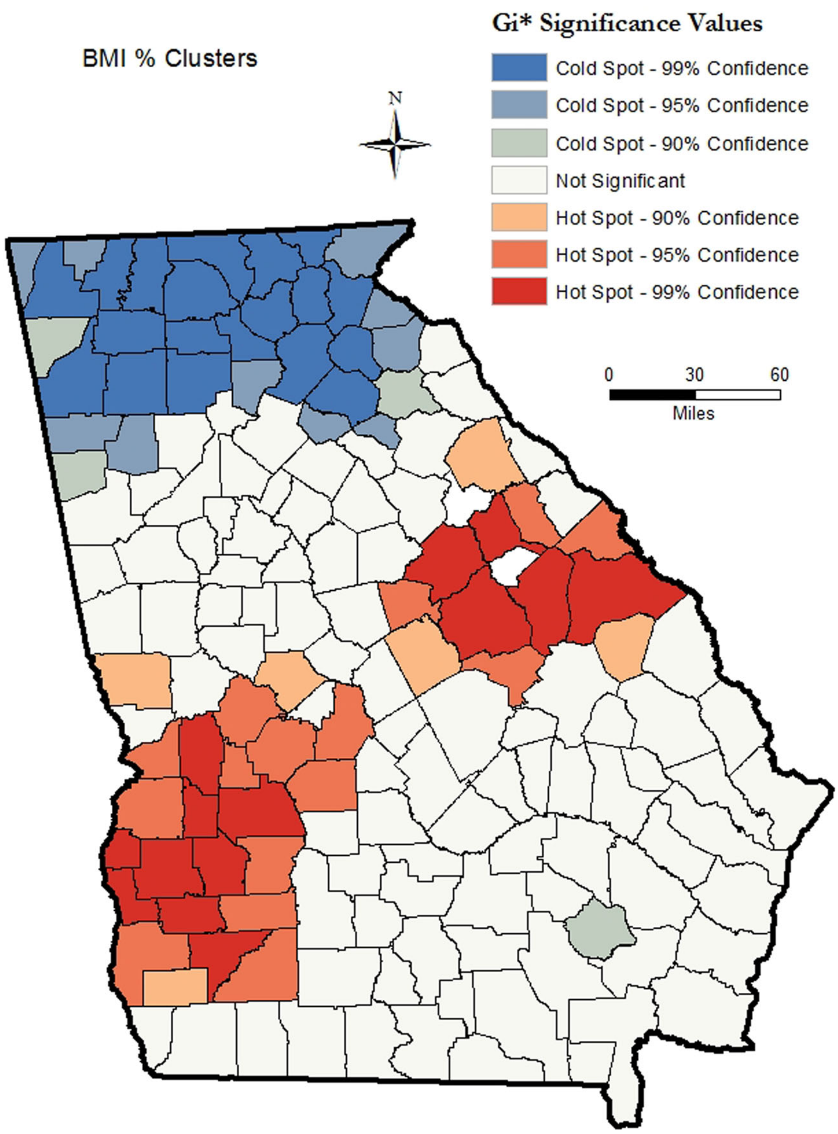

Figure 7 Georgia Clusters of Body Mass Index% Values.

With these exploratory results we can begin to better understand where morbid obesity occurs in the United States, in this case by county, and confirm that there are implications for COVID-19 risk that—at a minimum—deserve further investigation. If these results prove consistent over time, they have the potential to influence medical practice and public health policy.

More specifically, this research has the potential to have significant short-, medium-, and long-term impacts on practice and policy. In the short term, the findings suggest that areas with larger obese populations will need greater resources for effective treatment of COVID-19, as more cases and deaths should be

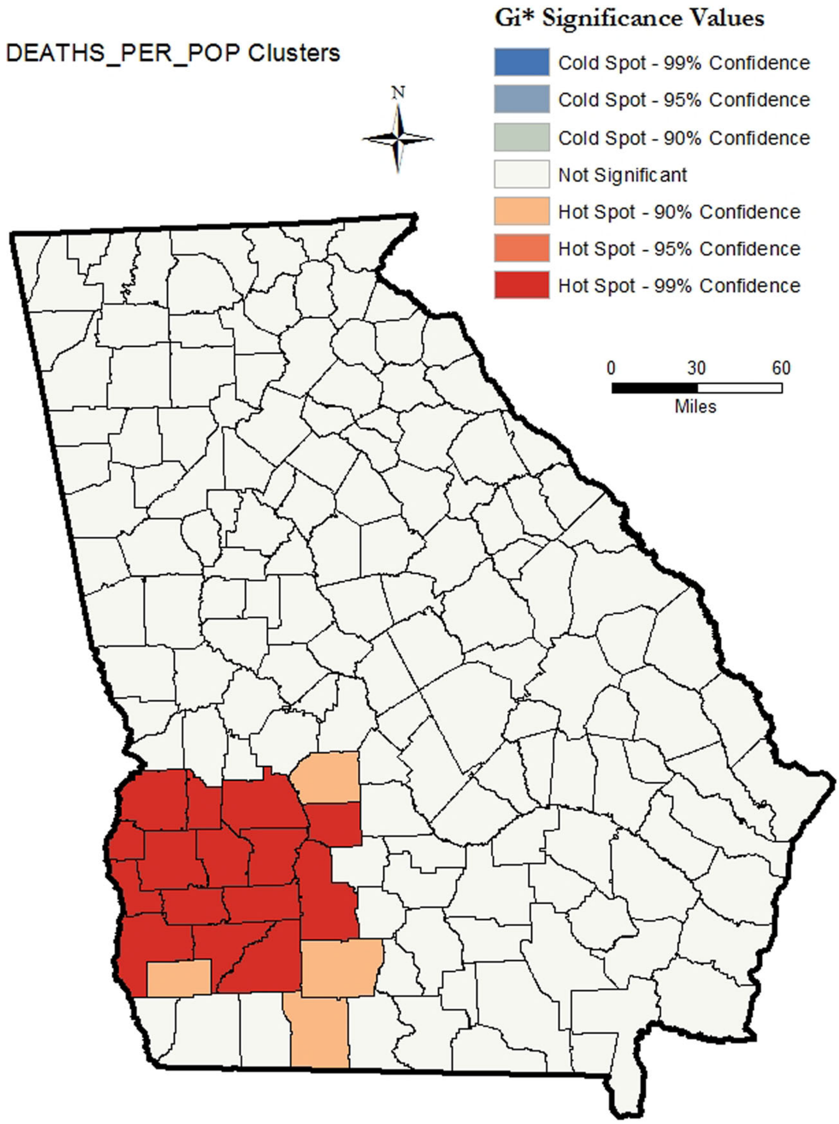

Figure 8 Georgia Clusters of DEATHS_PER_POP Values.

expected as compared with the general population. The recent crises regarding the lack of medical equipment and personnel (Ranney, Griffeth, & Jha, 2020) at the right place and the right time, make it clear that knowing the population at risk and the variations in need among those populations is critical for the most efficient allocation of resources. For example, there is specialized equipment required for morbidly obese hospitalization and care (e.g., specialized gurneys). Therefore, this equipment should be made available where it is most likely to be needed. There are well-developed models and methods for the prepositioning of resources and personnel (e.g., Curtin, Hayslett-McCall, & Qiu, 2010), and for distribution and

Table 3. Association of High Body Mass Index (BMI%) Clusters With High DEATHS_PER_POP Clusters

State	No. in High BMI% Clusters	No. High DEATHS_PER_POP Clusters	No. in Both
Alabama	16	7	1
California	13	8	5
Florida	7	4	1
Georgia	35	20	15
Illinois	10	12	7
New York	9	6	6
Pennsylvania	5	14	5
South Carolina	8	8	3
Texas	56	22	7
Viginia	29	21	11
Washington	6	6	3

logistics, but the effectiveness of these methods depends entirely on a comprehensive understanding of the nature of the demand for those resources. Knowledge of the variability of the populations at risk, particularly concerning their locations, should lead to variations in the distribution of resources and personnel to test, contain, trace, inform, and treat the population.

In the long term, these results provide a compelling motivation to address obesity through public policy and public health practice. We have described earlier that obesity can complicate and be an added risk factor to developing or dying from respiratory viruses in general. These data better solidify such a relationship with COVID-19 and suggest that obesity needs to be examined not only with COVID-19, but with future similar respiratory illnesses. In a recent analysis, researchers reported the need to ensure good micronutrient status to prevent serious complications from COVID-19 infection, as many micronutrients including Vitamin C and D are critical to maintaining a healthy immune system (Calder, Carr, Gombart, & Eggersdorfer, 2020). Several studies have shown that morbidly obese individuals are often deficient in micronutrients, which further complicates the risk of obese individuals being infected with COVID-19 as well as with other infectious diseases (Aasheim, Hofsø, Hjelmesaeth, Birkeland, & Bøhmer, 2008). Such new evidence, coupled with our results, reinforces the critical need for continued public health interventions that focus on reducing obesity and improving nutrition.

Further, the findings have some global health implications, particularly in those countries affected by the dual burden of disease (Popkin & Gordon-Larsen, 2004). In these countries, we see a pattern of change where high prevalence of infectious diseases associated with malnutrition, periodic famine, and poor environmental sanitation is shifting to one of high prevalence of chronic and degenerative disease associated with urban–industrial lifestyles. Our findings reveal a clear relationship with infectious disease and noncommunicable diseases, and suggest it is critical to not overlook the impact of obesity when developing infectious disease control measures. Further, here in the United States, these findings suggest a greater need to focus and commit resources to obesity prevention programs and policy.

Limitations and Bias

While these findings have major implications for policy and practice, it is important to recognize there are several limitations to the data that will require further analyses and future studies.

Obesity Data

Regarding the NHANES BMI data, when this period of rapid response need abates, the estimates of morbid obesity should be updated to reflect the most recent NHANES survey. The NHANES data were collected from 1999 to 2006 and changes since then regarding obesity should be considered (Mozumdar & Liguori, 2011). For example, the estimated U.S. prevalence of morbid obesity among adults over 20 years of age was 5.9 percent in 2006 with a 0.5 percent standard error. The most recent NHANES data from 2018 show an increase of morbid obesity to 9.2 percent with a 0.9 standard error (Hales, 2020). This change does suggest that our estimates of the population with morbid obesity are conservative. There is no evidence that the authors are aware of that suggests that the relative prevalence of morbid obesity among gender and race groups has changed significantly, and therefore the estimates of the population with BMI $\geq$ 40 are likely low, but still representative of the overall distribution nationwide. Moreover, while the 2000 Census data were appropriate to use with the 2006 NHANES data, matching data by date between the Census and NHANES in future studies is advised.

Further, these analyses only consider the U.S. population aged 18–64 years, so we cannot extend these results to the global population at this time. As increased age is a significant indicator of risk of death from COVID-19 it is important that the elderly population be included in future analyses. We are also comfortable in reporting data from this age group as recent analyses suggest that obesity plays a greater role in aggravating symptoms for those under 60 years of age. For those over 60 years, obesity appears to play less of a role (Lighter et al., 2020). We do not include children in this analysis as risks from obesity can differ significantly from those in the population studied here (Hales, 2020; Hedley et al., 2004; The State of Childhood Obesity, 2019) and is measured with different variables (BMI-for-age percentiles) and cannot control for the impact of variation in growth and development. Another limitation is inherent in the use of BMI (which is a ratio using height and weight measurements). While one of the more useful and common indicators for obesity comparisons across populations, it does not directly measure fat tissue in individuals, which is more directly associated with chronic disease risk.

COVID-19 Data

Regarding the COVID-19 data, outcomes are changing everyday, and this analysis should be reassessed when the pandemic has ended to determine whether or not the associations between obesity and outcomes persist. If they do not, it may indicate that the obese population was more at risk in the earlier stages of the pandemic, and that a temporally informed analysis may be indicated. Further, this is limited by the time sensitive nature of the call for research given the pressing need to address the pandemic. There are many additional variables that can and should be examined in the context of COVID-19. Finally, because of the widespread shortage of testing, the data may be limited in the picture it presents of the outbreak and again adds to the importance of re-examining the data when the pandemic is over.

Conclusions

These findings explore relationships between morbid obese individuals and COVID-19 cases and deaths within the United States at the county level. The analyses examine aspatial and spatial associations between BMI ≥ 40 and COVID-19 negative outcomes. Overall we see statistically significant relationships between morbid obese individuals and cases and deaths of COVID-19. While there are some limitations and future analyses needed to better understand such relationships, they do suggest that regarding the COVID-19 crisis, health practioners and policymakers need to understand the impact that morbid obesity plays with COVID-19 in order to respond to this and similar emerging infectious diseases in future. Such information can play a role in identifying resource needs as well as informing mitigation policies.

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Notes

Conflicts of interest: None declared.

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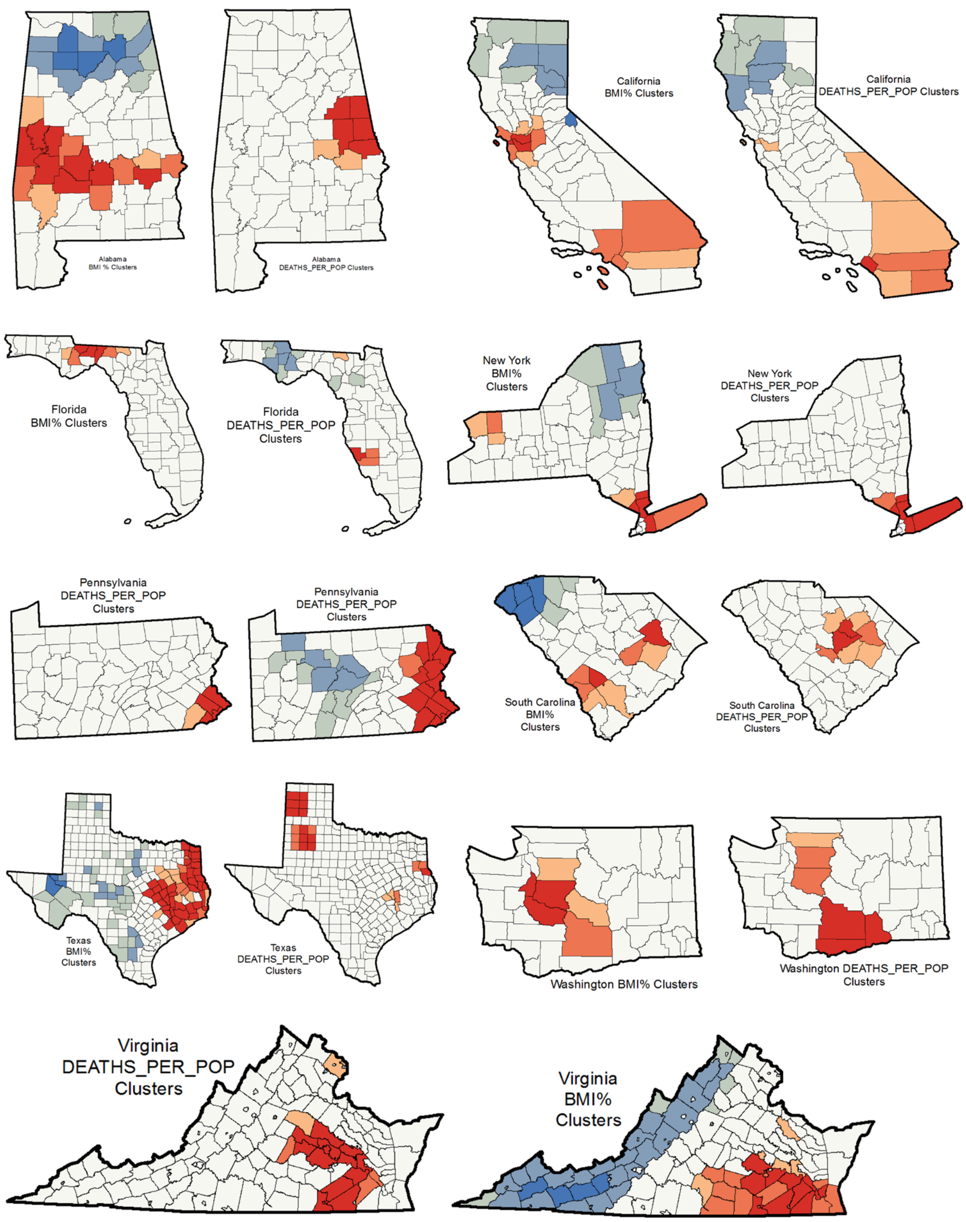
Appendix: Cluster Maps—BMI% and DEATHS_PER_POP



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