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POLICY ANALYSIS

Heterogeneity of the Association Between Obesity and COVID-19 Mortality and the Roles of Policy Interventions: U.S. National-Level Analysis

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This article examines the heterogeneity of the association between obesity and COVID-19 mortality across various dimensions, including COVID-19 vaccination rates, mask mandates, gathering restrictions, and household income. Using multivariate regression analysis on U.S. county-level data over 2020–2021, the authors found that county-level adult obesity rates were positively associated with COVID-19 death rates. The results suggest that on average, a 10-percentage-point decrease in adult obesity rate is associated with a decrease in COVID-19 deaths by 4.79%–5.98% in the U.S. Considering that the average adult obesity rate in the U.S. is higher than the global average, this finding may explain why deaths due to COVID-19 were disproportionately large in the U.S. In addition, the authors found that association between obesity and the COVID-19 death rate is much more pronounced in groups with low vaccination rates, weak mask mandates, loose gathering restrictions, or low household incomes, indicating the importance of COVID-19 response policies and income to people with obesity facing a pandemic. The study results contribute to policy discussions surrounding preparation for COVID-19–like pandemics. Food policies and health promotion strategies that encourage physical well-being to reduce obesity prevalence may help reduce mortality in future pandemics.

INTRODUCTION

Although the clinical association between obesity and coronavirus disease 2019 (COVID-19) mortality is well established, few studies have examined how the COVID-19 vaccination rate, mask mandates, gathering restrictions, and household income subsidies moderate this association.[1–5] This is an important gap because understanding how these response strategies or policy interventions may moderate the association between obesity and COVID-19 mortality can inform future pandemic responses, particularly for people with obesity. This study aims to fill this gap.

Existing studies either use small samples of hospitalized patients to examine the relationship between obesity and the risk of COVID-19 infection, severity, and death, or use cross-country samples from early period in the COVID-19 pandemic to show that the average BMI of a country is a significant predictor of COVID-19 deaths.[6–12] This study complements existing studies using the population-level COVID-19 mortality and obesity data within a country (the U.S.) to examine the association between obesity and COVID-19 mortality, enabling the avoidance of two issues of previous studies: small samples and

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potentially inconsistent definitions of COVID-19 mortality across countries.

METHODS

Study Sample

The study sample includes data on the cumulative number of COVID-19 deaths of 2,392 counties in the contiguous U.S. as of December 31, 2021. Data from Florida were excluded because >40% of COVID-19 deaths in this state are not assigned to any specific counties and are instead listed as statewide unallocated. Owing to a significant portion of missing values, data from Texas are not included in the study sample either.

Measures

Data for the county-level cumulative number of COVID-19 deaths as of December 31, 2021 were obtained from USAFacts, as were the data for the county-level population in the year 2019.[13] The outcome variable was constructed as the number of COVID-19 deaths per thousand people. The authors obtained the adult obesity rate for each county from CHR&R (County Health Ranking and Roadmaps).[14] The average county-level COVID-19 death rate is 3.04 per 1,000 people, and adult obesity rate is 34% (Appendix Table A1, available online). There is substantial intercounty variability in the COVID-19 death rate, ranging from 0 to 9.81 deaths per 1,000 people (Figure 1A), as well as for the adult obesity rate, ranging from 11% to 59% (Figure 1B).

The authors obtained the percentage of people who received the second dose of COVID-19 vaccine through the end of 2021 from the Centers for Disease Control and Prevention.[15] The authors obtained data for the number of effective days under mask mandate in a state over 2020−2021 from Ballotpedia.[16] Information on whether the state had implemented gathering restrictions and whether the state had closed nonessential businesses during the early pandemic period was obtained from American Legislative Exchange Council.[17]

Because political preference may influence policy choice and policy compliance, which then have an impact on the spread of COVID-19, the authors furthermore obtained data for the percentage of voters who voted for the Republican candidate in the 2020 election from Harvard Dataverse.[18] Climate affects daily activities and, thus, the extent to which people come in contact with potentially infected individuals, potentially impacting COVID-19 transmission.[19−22] Because average temperature may roughly represent the overall climatic conditions in a county, the authors obtained the average temperature for each county and each month in 2020−2021 from National Centers for Environmental Information and calculated the average temperature for each county over the period.[23,24] The authors also obtained the county's 2019 median household income, proportion African American, proportion elderly, and 2010 proportion living in a rural area from the U.S. Census Bureau. The authors obtained the percentage of households who were food insecure in 2018 from the Map the Meal Gap. Appendix Table A1 (available online) summarizes all the variables used in the analysis.

Statistical Analysis

To measure the association between the county-level adult obesity rate and COVID-19 mortality and how the association is moderated by key policies, the authors used multivariate regression analysis with interaction terms. The primary independent variable of interest was the adult obesity rate. The authors also controlled for important COVID-19 response policies and sociodemographic measures. To test how vaccination, mask mandate, gathering restrictions, and household income moderated the association between adult obesity and COVID deaths, the authors interacted adult obesity with these variables in separate regressions, with each regression including only 1 interaction term.

The authors considered 5 different model specifications. Model 1 consisted of all explanatory variables of interest but did not include any interaction terms. Model 2 included all variables in Model 1 and added the interaction between adult obesity (%) and the COVID-19 vaccination rate (%). Similarly, Model 3, Model 4, and Model 5 included all variables in Model 1 but added interactions of adult obesity (%) with mask mandate, gathering restriction, and median household income, respectively. The equations for Model 1 and Models 2−5 are presented in the Appendix (available online).

RESULTS

Table 1 presents the results, focusing on variables of interest. Full regression results are in Appendix Table A2 (available online). Higher county-level obesity is associated with a higher COVID-19 death rate (Model 1). Higher vaccination rates, more days under mask mandate, gathering restriction, and higher income all weaken the relationship between obesity and COVID-19 mortality (Models 2−5). Appendix Table A3 (available online) uses these models to calculate U.S. COVID deaths if the adult obesity rate had been 10-percentage-points lower. Depending on the model, COVID-19 deaths would have been reduced by 4.79%−5.98% (or 53,103−66,379 deaths). To put these numbers in perspective, the results from Models 2−4 imply that vaccination policies reduced mortality by 482,408; mask mandates reduced

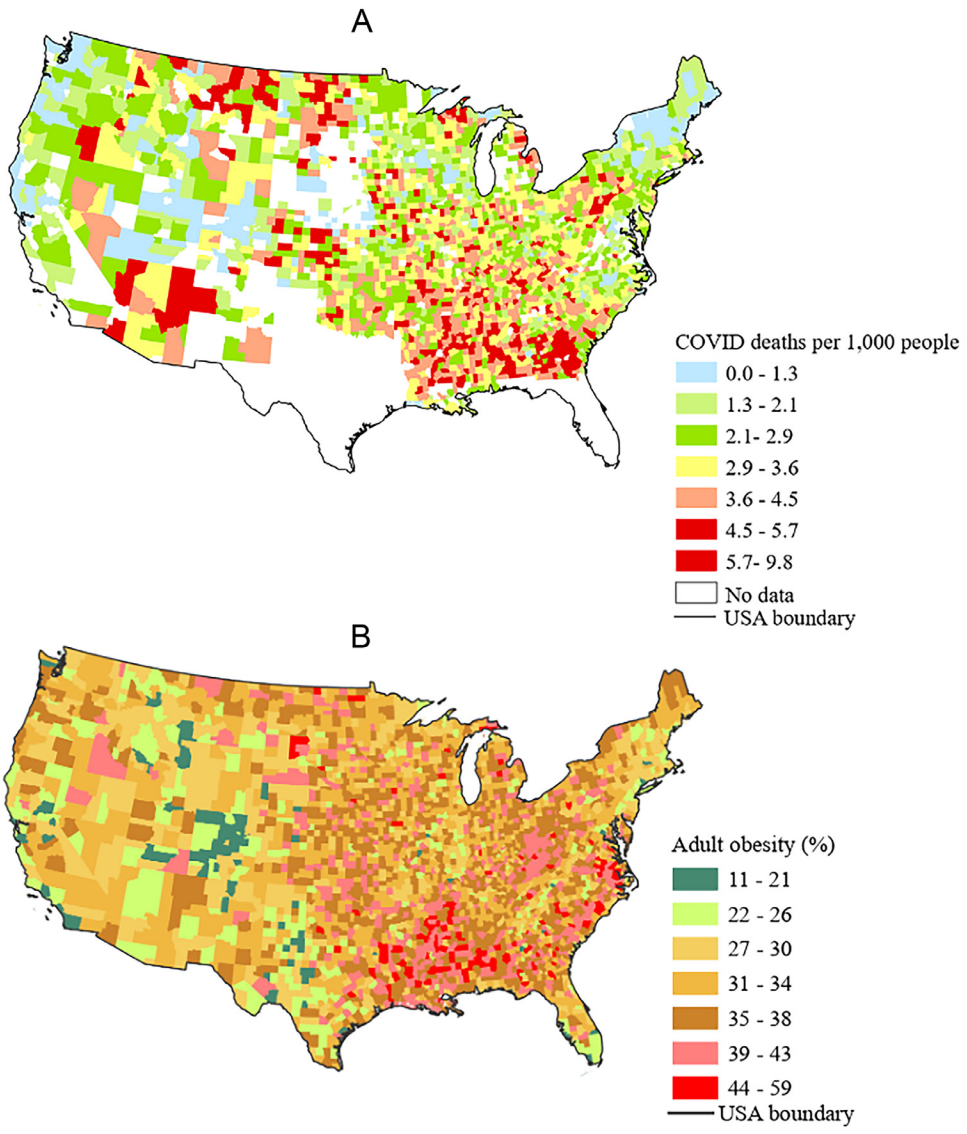

Figure 1. US county-level COVID-19 death rate and adult obesity rate. (A) County-level COVID-19 death rate (deaths due to COVID-19 over years 2020 and 2021 per 1,000 people) and (B) adult obesity rate (%) in U.S. in year 2019.
Note: The data source of COVID-19–associated death count is USAfacts, and the source of county-level obesity rate (%) is CHR&R (County Health Ranking and Roadmaps).

by 6,346; and gathering restrictions reduced by 203,119 (Appendix Table A3, available online, provides the calculations).

In Figure 2, the authors mapped the number of lives per 100,000 people that could have been saved in each county by decreasing the obesity rate by 10 percentage points on the basis of Model 1. The map shows that counties in the Western U.S., Northeast U.S., and counties with large cities would experience a large decrease in COVID-19 deaths due to a reduction in obesity rate.

Appendix Tables A4 and A5 (available online) show additional results when the authors further include 2 additional health-related risk factors that are also risk factors for COVID-19 mortality.[25] One is diabetes prevalence (obtained from County Health Ranking and Roadmaps), and the other is cardiovascular disease (obtained from the Centers for Disease Control and Prevention).[14,26] Study findings that COVID-19 policies mitigate the relationship between obesity and COVID-19 mortality are consistent in these models.

The results presented in Table 2 showed that there is heterogeneity in the association between COVID-19 mortality and the obesity rate, depending upon the vaccination rate, mask mandate, gathering restriction, and median household income of a county. In the analysis described earlier, the authors evaluated the association

Table 1. Relationship Between U.S. County-Level COVID-19 Death Rate (Per 1,000 People) and Adult Obesity Rate (%)

	Model				
Variable	1 NA	2 AOR × VR	3 AOR × MM	4 AOR × GR	5 AOR × MHI
Adult obesity (%)	0.0180[a] (0.008)	0.0630[a] (0.026)	0.0450[b] (0.013)	0.0370[c] (0.0127)	0.1101[b] (0.020)
Vaccination (%)	−0.004 (0.007)	0.027 (0.0170	−0.004 (0.007)	−0.003 (0.007)	−0.005 (0.007)
Adult obesity (%) × vaccination (%)		−0.0009[d] (0.0006)			
Mask mandate (MM)	−0.0006 (0.004)	−0.0005 (0.0004)	0.004[c] (0.0013)	−0.0006 (0.0004)	−0.0005 (0.0004)
Adult obesity (%) × mask mandate (MM)			−0.00012[c] (0.000039)		
Gathering restriction	0.021 (0.163)	0.024 (0.163)	0.013 (0.160)	1.068[e] (0.54)	0.010 (0.1623)
Adult obesity × gathering restriction				−0.030[a] (0.014)	
Median household income (thousands)	−0.026[b] (0.005)	−0.028[b] (0.005)	−0.027[b] (0.005)	−0.026[b] (0.005)	0.021[a] (0.011)
Adult obesity (%) × median household income					−0.0017[b] (0.00035)
Number of observations	2,392	2,392	2,392	2,392	2,392

Notes: NA indicates that the model has no interaction term. MM is in days. The value in parentheses denotes the robust SE. The full results are in Appendix Table A2 (available online).
[a]Denotes 5% level of significance.
[b]Denotes 0.1% level of significance.
[c]Denotes 1% level of significance.
[d]Denotes 11% level of significance.
[e]Denote 10% level of significance.
AOR, adult obesity rate; GR, gathering restriction; MHI, median household income; MM, mask mandate; VR, vaccination rate.

at the sample means. To illustrate the heterogeneity, the authors also evaluated the association at lower and higher values of the relevant variables. Results from Model 2 implied that in counties whose vaccination rate is at the 25th (respectively 50th) percentiles in the sample, a 1-percentage-point increase in adult obesity rate was related to 0.039 (respectively 0.016) more COVID-19 deaths per 1,000 people. For a county with a vaccination rate at above 75th percentile, the association between obesity and COVID-19 deaths was statistically insignificant.

Similarly, for counties at the 25th-percentile number of days under the mask mandate (Model 3), a 1-percentage-point increase in obesity was related to 0.042 more COVID-19 deaths per 1,000 people, whereas in a county with a number of days under mask mandate (75th percentile), this relationship drops to 0.036, a 14.3% decrease in magnitude. When there is no gathering restriction in a county (Model 4), the association between adult obesity rate and COVID mortality was positive and statistically significant. However, in the presence of gathering restrictions, the association between adult obesity rate and COVID-19 mortality was statistically insignificant. Similar conclusions can be drawn regarding the mitigating impact of household income on the association (Model 5).

DISCUSSION

The authors found that county-level adult obesity rates were positively associated with COVID-19 death rates in the U.S. Considering that the average adult obesity rate in the U.S. is higher than the global average (33% vs 16%), this finding may help explain why deaths due to COVID-19 were disproportionately large in the U.S. (16.76% of global COVID-19 deaths) compared with its population share (5%) in the world.[27–29]

Furthermore, the authors found that COVID-19 policies moderated the association between adult obesity rate and COVID-19 mortality. Counties with low vaccination rates, no mask mandates, loose gathering restrictions, or low household income had much stronger positive associations between adult obesity rate and COVID-19 mortality. The authors thus find that vaccinating against COVID-19, wearing masks, maintaining social distancing, and providing income subsidies can weaken the association of obesity and county-level COVID-19–associated mortality. Although COVID-19 policies may protect both individuals with obesity and non-obese individuals with similar efficacy,[30] the study findings suggest that these policies may save the lives of individuals with obesity at higher rates than those of individuals without obesity because of the higher underlying clinical risk of COVID-19 mortality among individuals with obesity. Existing research shows that the average obesity rate among adults in the world is growing.[29] In this regard, the study findings highlight the urgency of combating obesity to prepare for future pandemics. Because obesity is a chronic condition, efforts to address it should be focused on preventive measures rather than treatments. Thus, behavioral factors and food policies may have a particular role in

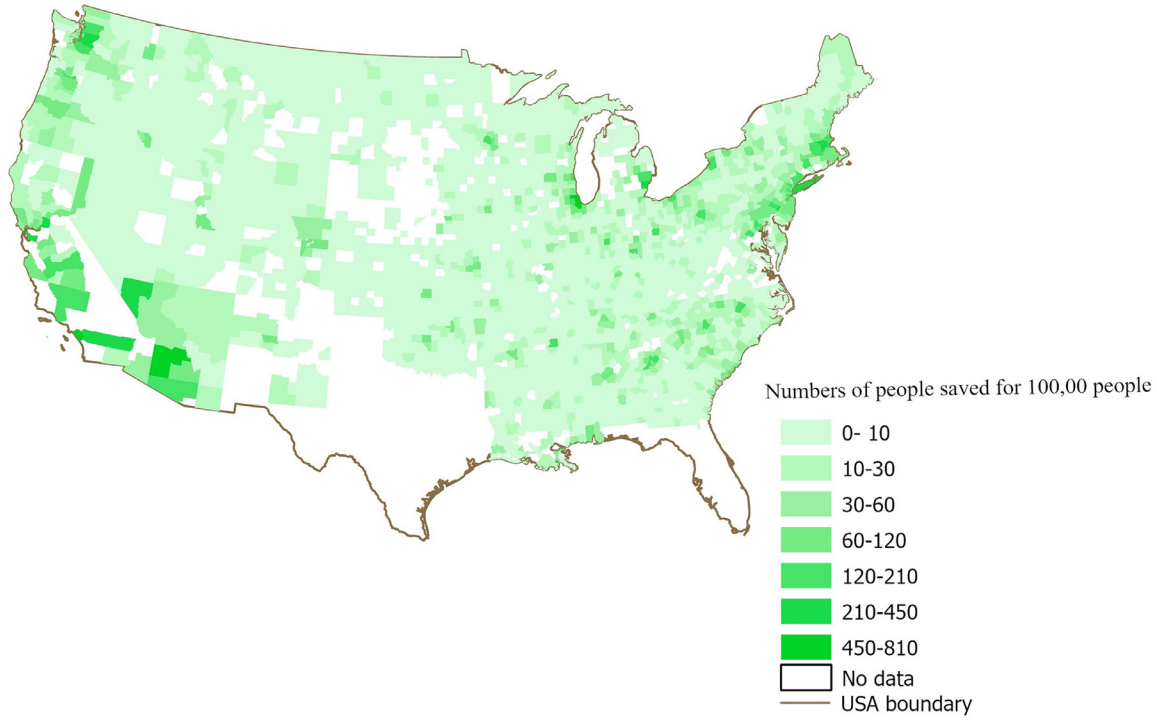

Figure 2. The number of fewer COVID-19 deaths (per 100,000 people) by reducing the obesity rate (%) by 10 percentage points in each county (Model 1).
Notes: The county with a higher intensity of green color represents the county for which a higher number of people's lives could be saved by reducing the obesity rate (%), holding other factors constant. The description of Model 1 is presented in the statistical analysis section of this paper.

tackling obesity and, thus, in preparing for future pandemics.[31,32]

Despite the proven effectiveness of COVID-19 vaccines, a significant portion of the population are reluctant to receive vaccinations, which can lessen heard immunity and increase mortality from infectious diseases, particularly for people with obesity.[33] The study results highlight the need to understand vaccine hesitancy among individuals with obesity and the potential importance of targeting vaccine incentive and awareness campaigns to individuals with obesity.[34] In addition, incentive and awareness campaigns for nonpharmaceutical policy interventions can be targeted to individuals with obesity. The results also highlight the feedback between acute and chronic diseases. Widespread health promotion strategies that encourage physical well-being and healthy dietary habits to reduce obesity prevalence may also

Table 2. Heterogenous Impact of Obesity Rate on COVID-19 Deaths

Marginal impact of obesity	Model 2 AOR × VR	Model 3 AOR × MM	Model 4 AOR × GR	Model 5 AOR × MHI
Evaluated at 25th percentile	0.039[a] (0.013); 95% CI=0.013, 0.065	0.042[a] (0.011); 95% CI=0.018, 0.066		0.067[a] (0.013); 95% CI=0.041, 0.093
Evaluated at 50th percentile	0.016[b] (0.009); 95% CI= −0.003, 0.035	0.039[a] (0.011); 95% CI=0.017, 0.061		0.024[a] (0.009); 95% CI=0.007, 0.04
Evaluated at 75th percentile	−0.007 (0.021); 95% CI= −0.05, 0.035	0.036[a] (0.010); 95% CI=0.015, 0.060		−0.019 (0.011); 95% CI= −0.042, 0.005
Gathering restriction (no)			0.036[a] (0.013); 95% CI=0.011, 0.062	
Gathering restriction (yes)			0.006 (0.009); 95% CI= −0.012, 0.0247	

Notes: MM is in days. The value in parentheses shows the SE of the estimates.
[a]Denotes 0.1% level of significance.
[b]Denotes 10% level of significance.
AOR, adult obesity rate; GR, gathering restriction; MHI, median household income; MM, mask mandate; VR, vaccination rate.

enhance a population's ability to recover from acute disease and future pandemics.[35–37]

Finally, the findings on the heterogenous association between the obesity rate and the COVID-19 death rate across vaccination rates, mask mandate, gathering restriction, and household income underscore the importance of COVID-19 response policies and income to people with obesity facing a pandemic.

Limitations

There are some limitations to this study. First, focusing on the association between obesity and COVID-19 deaths, this study does not seek a causal interpretation of results. Another limitation is that the county-level data do not capture the differential policy compliance between people with obesity and those without. If individuals with obesity were less likely to comply with the policies, they would experience greater COVID-19 infection rates and mortality. The authors are not aware of policy compliance data for individuals with obesity and those without separately and are thus unable to test whether this is a mechanism underlying the study result. Furthermore, the authors are only able to identify whether a state had gathering restrictions and not the length of time that gathering restrictions were in place. This masks the heterogeneity in policy implementation across states. Owing to data limitations, the authors are unable to account for this policy heterogeneity in the analysis. The authors also acknowledge that average temperature is a coarse measure of climate conditions within a period. Future research can be conducted to address these limitations.

CONCLUSIONS

This study finds a positive association between the adult obesity rate and the COVID-19 mortality rate. The association between obesity and COVID-19 mortality is much more pronounced in groups with low vaccination rates, weak mask mandates, loose gathering restrictions, or low household income.

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SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.focus.2024.100312.

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