

Post-lockdown infection rates of COVID-19 following the reopening of public businesses

Alexander Bruckhaus[†], Aubrey Martinez[†], Rachael Garner, Marianna La Rocca, Dominique Duncan

Laboratory of Neuro Imaging, USC Stevens Neuroimaging and Informatics Institute, Keck School of Medicine of USC, University of Southern California, 2025 Zonal Ave., Los Angeles, CA 90033, USA

Address correspondence to Alexander Bruckhaus, E-mail: bruckhau@usc.edu.

[†]Contributed equally to this work.

ABSTRACT

Background The Coronavirus Disease 2019 (COVID-19) pandemic warranted a myriad of government-ordered business closures across the USA in efforts to mitigate the spread of the virus. This study aims to discover the implications of government-enforced health policies of reopening public businesses amidst the pandemic and its effect on county-level infection rates.

Methods Eighty-three US counties ($n = 83$) that reported at least 20 000 cases as of 4 November 2020 were selected for this study. The dates when businesses (restaurants, bars, retail, gyms, salons/barbers and public schools) partially and fully reopened, as well as infection rates on the 1st and 14th days following each businesses' reopening, were recorded. Regression analysis was conducted to deduce potential associations between the 14-day change in infection rate and mask usage frequency, median household income, population density and social distancing.

Results On average, infection rates rose significantly as businesses reopened. The average 14-day change in infection rate was higher for fully reopened businesses (infection rate = +0.100) compared to partially reopened businesses (infection rate = +0.0454). The P -value of the two distributions was 0.001692, indicating statistical significance ($P < 0.01$).

Conclusion This research provides insight into the transmission of COVID-19 and promotes evidence-driven policymaking for disease prevention and community health.

Keywords communities, epidemiology, public health

Introduction

By 11 March 2020, the severity and spread of Coronavirus Disease 2019 (COVID-19) warranted the World Health Organization (WHO) to declare it as a global pandemic.¹

Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) virus can spread via contact, airborne, or droplet transmission.² Due to its highly transmissible nature, coupled with evidence that asymptomatic people can spread SARS-CoV-2^{3,4} without knowing they are infected, the CDC recommends non-pharmaceutical interventions such as social distancing, mask usage and avoidance of mass gatherings and crowded indoor spaces.⁴

In accordance with these recommendations, governments worldwide required closures of non-essential businesses and issued stay-at-home orders. The role of such lockdowns in slowing COVID-19 has been widely studied. Two separate

studies in Switzerland and Spain demonstrated that lockdown procedures were an effective mitigation strategy.^{5,6} Another study across 11 European countries correlated early sustained intervention with a decrease in viral reproduction.⁷ Further

Alexander Bruckhaus, Undergraduate Research Fellow at the Laboratory of Neuro Imaging at the University of Southern California Stevens Neuroimaging and Informatics Institute

Aubrey Martinez, Undergraduate Research Fellow at the Laboratory of Neuro Imaging at the University of Southern California Stevens Neuroimaging and Informatics Institute

Rachael Garner, Project Specialist at the Laboratory of Neuro Imaging at the University of Southern California Stevens Neuroimaging and Informatics Institute

Marianna La Rocca, Postdoctoral Scholar at the Laboratory of Neuro Imaging at the University of Southern California Stevens Neuroimaging and Informatics Institute

Dominique Duncan, Assistant Professor of Neurology, Neuroscience, and Biomedical Engineering at the Laboratory of Neuro Imaging at the University of Southern California Stevens Neuroimaging and Informatics Institute

research shows regions that initiated school and workplace closures^{8,9} prior to complete lockdown, or declared lockdown early on,¹⁰ experienced much lower rates of infection. Despite this, economic hardships following lockdown¹¹ prompted local governments to reopen businesses—potentially placing residents at risk of infection by community spread. Currently, there is a lack of research regarding COVID-19 trends following the reopening of public businesses. Only recently, the impact has been investigated; a CDC report released in March 2021 found an association between restaurant reopenings and increased daily COVID-19 case growth and death rates.¹²

To understand the effects of early reopening policies, we analyzed the 14-day change in infection rate following the reopening of six highly trafficked business types in 83 US counties. Then, we investigated the relationship between business-associated changes in infection rate and additional variables: mask usage frequency, median household income, population density and social distancing.

Methods

Counties studied

Data used in preparation of this article were obtained from the COVID-19 Data Archive (COVID-ARC) powered by the Laboratory of Neuro Imaging (LONI) funded by the National Science Foundation. For up-to-date information on the study, visit <https://covid-arc.loni.usc.edu/>. Through COVID-ARC, we accessed a publicly available New York Times data set: <https://github.com/nytimes/covid-19-data/> containing COVID-19 cases counts from state and local governments and health departments. The data were filtered to extract US counties that reached 20 000 confirmed cases of COVID-19 as of 4 November 2020. Across the USA, 84 counties satisfied these conditions. One region, New York City (NYC), was excluded from the analysis because it was considered as one county by the New York Times data set, but it is composed of five separate boroughs and therefore did not allow for uniform comparisons. This refined data set of 83 counties focused on populations with existent rampant outbreaks so that post-lockdown transmission trends could be studied in detail. County-level data were used because reopening procedures were largely determined by local governments, allowing for more granular evaluation of changes related to local policymaking.

Infection rate metric

In this study, we analyzed the 14-day change in infection rates following the reopening of public businesses. Infection rate describes the number of new infections that arise from a

single new infection to estimate the number of additional people one infectious person can infect. Infection rate data was gathered from: <https://covidactnow.org/?s=1476432>. A 14-day time frame was used because the estimated incubation period for SARS-CoV-2 ranges from 2–14 days.¹³

Businesses studied

Restaurants, bars, non-essential retail, gyms/fitness facilities, public schools, salon/barbers and houses of worship were examined as potential drivers for the spread of COVID-19. To analyze the change in infection rate, we first identified the date each business type was permitted to reopen in each county. Since most reopenings were graded, we isolated two types of reopening: ‘partial reopening’ and ‘full reopening.’ In general, ‘partial reopening’ referred to reopening with restrictions such as capacity limits. ‘Full reopening’ referred to reopening with no restrictions. Supplementary material provides more comprehensive definitions of ‘partial reopening’ and ‘full reopening’ pertaining to business type.

Identification of reopening dates

Once classifications for ‘partial’ and ‘full’ reopening were well defined, we systematically reviewed official documentation to identify the date each business entered the partial/full reopening phase. The procedure for parsing government orders is outlined in Notes in supplementary material.

The closing, partial reopening and full reopening date for each business type was recorded for all businesses in all 83 counties. This information can be found in [Supplementary Table S1](#).

Data analysis

Average change in infection rate

After compiling critical dates for 83 counties, the infection rates corresponding to the 1st day of partial/full reopening and the 14th day of partial/full reopening were collected. Then, the change in infection rate was calculated by subtracting the infection rate of the 1st day of reopening from the 14th day after reopening. This was done to compute the change in infection rate following reopening of each business type.

The average change in infection rate was then calculated for each business category. For example, [Supplementary Table S2](#) reports the infection rate data corresponding to the 1st and the 14th days of partial reopening for the retail category. This analysis provides insight into how a county’s infection rate fluctuates following the 14-day period of businesses reopening and the impact each business reopening has on the county’s overall infection rate.

Factors driving infection rate

We evaluated the association of each county's respective infection rate changes with different independent variables:

1. County mask use frequency (never, rarely, sometimes, frequently and always).¹⁴
2. County median household income.¹⁵
3. County population density (people per square mile (1.609 km)).¹⁶
4. Change in mobility by state data acquired from <https://covid19.healthdata.org/united-states-of-america?view=infections-testing&tab=compare&test=infections>.

This analysis helps determine whether the infection rate change is associated with additional variables. Refer to Notes in supplementary material for a comprehensive explanation of mask usage frequency and change in mobility by state.

To gain an effective understanding of a possible relationship between infection rate and county mask use frequency, we ran multiple linear regression models in R (version 4.0.03).¹⁷ For the remaining categories, we used simple linear regression.

Results

Average change in infection rate

Partially reopened

The average infection rate change 14 days after the partial reopening of six business types (with restaurants now differentiated into two distinct groups based on seating, outdoor only and indoor/outdoor) is shown in Fig. 1A. Among businesses that partially reopened, bars were associated with the highest change in infection rate (+0.0836, $n = 67$), then gyms (+0.0638, $n = 80$) and indoor/outdoor restaurants (+0.0564, $n = 83$). Outdoor-only restaurants reported moderate increases (+0.0442, $n = 26$), followed by public schools (+0.0346, $n = 57$), salons/barbers (+0.0197, $n = 76$) and retail (+0.0153, $n = 83$). The average change in infection rate after 14 days for all businesses was +0.0455.

Fully reopened

The average infection rate change 14 days after full reopening of six business types is shown in Fig. 1B. Among businesses that fully reopened, gyms were associated with the highest change in infection rate (+0.1320, $n = 10$), then salons/barbers (+0.1306, $n = 35$), retail (+0.1092, $n = 12$), indoor/outdoor restaurants (+0.0876, $n = 17$), schools (+0.0838, $n = 13$) and bars (+0.0585, $n = 13$). The average 14-day change in infection rate for all fully opened businesses was +0.100. This was significantly higher than the average 14-day change after partial reopening (+0.0454), with $P = 0.001692$.

Factors driving infection rate

These results highlight the relationships between the change in infection rate following specific business reopenings in each county and mask usage frequency, median household income, population density and social distancing.

There were 11 statistically significant relationships. Of these, we excluded four results as the small number and distribution of data points did not allow for appropriate statistical power. The four excluded relationships were:

1. Change in infection rate (full bar reopening) versus change in mobility by state.
2. Change in infection rate (full retail reopening) versus change in mobility by state.
3. Change in infection rate (partial restaurant (indoor/outdoor) reopening) versus change in mobility by state.
4. Change in infection rate (partial retail reopening) versus change in mobility by state.

The seven remaining statistically significant relationships are found in Tables 1 and 2.

The frequency of mask usage by county

Table 1 and Supplementary Fig. S1A–D show the significant associations ($P < 0.05$) between mask usage by county and change in infection rate. Actual infection rate versus predicted infection rate is visualized to show how the degree of mask usage can predict infection rates.

The median household income by county

Table 2 and Supplementary Fig. S2A–C show significant results ($P < 0.05$) between median household income and the change in infection rate. Fully reopened restaurants, bars, retail, gyms and salons/barbers showed no statistically significant results.

Population density of a county

No significant results were obtained from population density versus change in infection rate.

The change of mobility by state

No significant results were obtained from the change of mobility by state versus change in infection rate.

Discussion

Main findings of this study

As previously discussed, literature has demonstrated the effects of lockdowns in mitigating the spread COVID-19. However, there is little data-driven evidence on the effects of reopenings. Acknowledging these studies, we aimed to

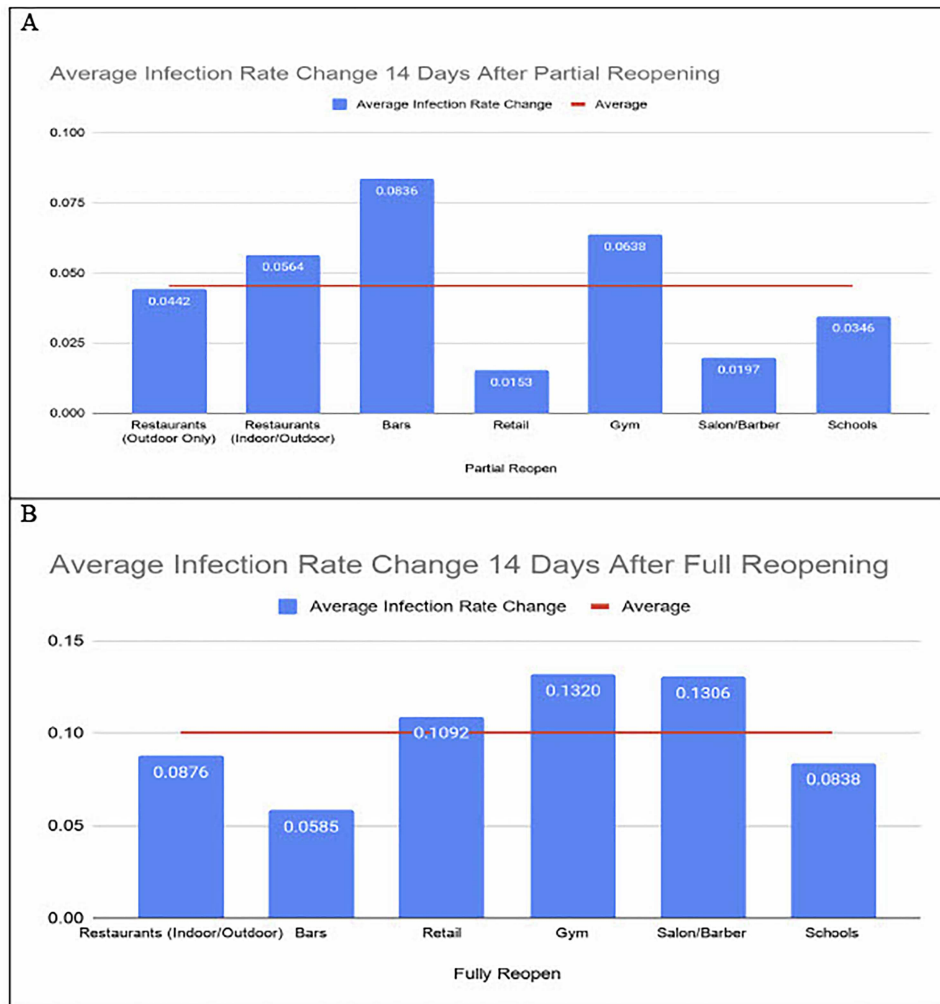


Fig. 1 (A) The average 14-day change in infection for each respective partially reopened business. The horizontal line indicates the average change in infection rate among all businesses. **(B)** The average 14-day change in infection for each respective fully reopened business. The horizontal line indicates the average change in infection rate among all businesses.

Table 1 Significant relationships between mask use frequency and the change in infection rate by business

Mask frequency	Adjusted multiple R-squared	P-value	n
Restaurants (partial indoor/outdoor)	0.1107	0.015	83
Bars (partially reopened)	0.1453	0.012	67
Bars (fully reopened)	0.7676	0.006	13
Gyms (partially reopened)	0.1064	0.020	80

Note: Partially reopened restaurants (outdoor only), retail, salons/barbers and public schools showed no statistically significant results. Fully opened restaurants, retail, gyms, salons/barbers and public schools showed no statistically significant results.

study the effects of post-lockdown reopenings by analyzing county-level infection rate changes. This perspective offers quantifiable insight into the effects of reopening businesses after local lockdowns and can be used to guide future policymaking.

Average change in infection rate—partial reopenings

Regarding partial reopenings, Fig. 1A shows that the partial reopening of bars (infection rate increase of +0.0836) was associated with the highest change in infection rate. Bar patrons are able to remain maskless while drinking, increasing

Table 2 Significant relationships between median household income by county and the change in infection rate by business

Median household income	Adjusted multiple R-squared	P-value	n
Restaurants (partial indoor/outdoor)	0.038	0.043	83
Bars (partially reopened)	0.1058	0.004	67
Public schools (fully opened)	0.2428	0.0499	13

Note: Partially reopened restaurants (outdoor only), retail, gyms, salons/barbers and public schools showed no statistically significant results. Fully opened restaurants, bars, retail, gyms and salons/barbers showed no statistically significant results.

the potential for droplet transmission. Furthermore, intoxicated patrons may become overly relaxed and less likely to adhere to COVID-19 safety guidelines. However, it is important to note that bars were among the last businesses to reopen, with some counties never allowing them to reopen. Therefore, some of the infection rate data we attributed to the reopening of bars may be confounded by prior reopenings of other businesses. The partial reopening of gyms (infection rate increase of +0.0638) had the second highest change in infection rate among partially reopened businesses. A primary concern with reopening gyms is the shared use of exercise machines, leading to droplet transmission from contact with infectious bodily fluids. Patrons are encouraged to sanitize equipment after use, but not all establishments have staff enforcing this protocol. Fitness classes are another concern; intense workouts in small spaces can create moist atmospheres with turbulent airflow, resulting in denser droplet transmission.¹⁸ Additionally, not all gyms require patrons to wear a mask while exercising, which can further increase the transmission potential. While masks are typically required upon entrance, some gyms allow patrons to remove masks while exercising; case reports from the CDC have linked infrequent mask use during high-intensity group workouts to COVID-19 outbreaks in Chicago, Illinois,¹⁹ and Honolulu, Hawaii.²⁰

Average change in infection rate—full reopenings

Regarding full reopenings, Fig. 1B shows that full reopening of gyms (infection rate increase of +0.132) was associated with the highest change in infection rate out of the businesses analyzed, followed by the full reopening of salons/barbers (infection rate increase of +0.131). As mentioned, not all gyms enforce mask wearing, and there is concern over shared equipment and exercise classes. However, this relationship may be influenced by the relatively smaller sample of fully open gyms ($n = 10$). For salons/barbers, the nature of the job does not allow stylists and patrons to maintain a distance of 6 ft. Furthermore, stylists must physically touch patrons. This is concerning for both droplet and contact transmission.

It is also important to note that, although bars were associated with the highest change in infection rate when they partially reopened, they were associated with the lowest change in infection rate when fully reopened. This can be because we are considering a smaller number of counties where bars fully reopened ($n = 13$) as opposed to counties where bars partially reopened ($n = 67$).

Mask usage frequency

The multiple regressions from Table 1 show that the change in infection rate following partial reopening of restaurants for indoor/outdoor dining ($P = 0.01475$), partial reopening of bars ($P = 0.01162$), full reopening of bars ($P = 0.006021$) and partial reopening of gyms ($P = 0.01975$) is associated with the degree of mask wearing. For indoor dining (restaurants) and drinking (bars), mask use is especially important. As shown in Supplementary Fig. S1A–D, actual infection rates versus predicted infection rates show a considerable R-squared value, revealing that mask usage frequency had a significant association with the increased change in infection rates among four business type reopenings. This is supported by a recent CDC report in which mask mandates were associated with a decrease in daily COVID-19 case growth and death rates.¹² Due to concerns of poor ventilation, the CDC classified on-site dining with indoor seating as high-risk for the spread of COVID-19.²¹ Furthermore, a pre-lockdown study determined a restaurant's air conditioning unit to be the conveyor of respiratory droplets, leading to the infection of multiple families.²² To protect against droplet transmission in enclosed spaces like restaurants, bars and gyms, mask use is strongly encouraged.²³ However, dining establishments allow their patrons to take off their masks while eating and drinking, thereby making them susceptible to infection.

Median household income

The linear regressions from Table 2 show that the change in infection rate following partial reopening of restaurants for indoor/outdoor dining ($P = 0.04271$), partial reopening of bars ($P = 0.003939$) and full reopening of public schools

($P = 0.04991$) is associated with the median household income. In [Supplementary Fig. S2A](#), there is a positive relationship between the median household income and change in infection rate following partial reopening of restaurants for indoor/outdoor dining. One potential reason for this trend is that counties with a higher median household income may have residents with more financial means to engage in activities like dining out, yielding a higher potential for the spread of COVID-19. Meanwhile, [Supplementary Fig. S2B](#) shows a negative relationship between the median household income and change in infection rate following the partial reopening of bars. Past literature shows a complex relationship between alcohol consumption and socioeconomic status (SES). A review of 28 studies found that, while the prevalence of alcohol consumption may increase with household income, individuals with low SES were more likely to suffer from negative alcohol-related consequences.²⁴ A 44-year longitudinal study found that, compared to higher-incomes, lower-incomes were associated with both higher odds of abstinence and of heavy drinking.²⁵ Correspondingly, a population-based study conducted by the CDC among binge-drinkers found that binge-drinking frequency and intensity (quantity consumed per occasion) was highest among low-income individuals.²⁶ However, even when drinking habits are controlled, lower SES individuals are more likely to develop alcohol-related problems due to a combination of increased social or environmental stressors with fewer resources available to mitigate them.²⁷ Existing research has identified debt as a driving factor for alcohol abuse.²⁸ With the rise of COVID-19, low-income families disproportionately experienced increased financial pressures, potentially leading to increased presence at bars following reopening. The literature suggests that low-income individuals may consume larger quantities of alcohol, so they may spend more time inside the bar during their visit, thereby increasing the risk of SARS-CoV-2 transmission. This is a possible explanation as to why we see a negative relationship between the median household income and change in infection rate following the partial reopening of bars. Finally, in [Supplementary Fig. S2C](#), there is a negative relationship between the median household income and infection rate change following full reopening of public schools. A possible explanation is that parents with higher SES may be able to afford to keep children at home from school. Meanwhile, working-class parents are more likely to push for public school reopenings because they are unable to stay at home and help their children comply with online learning.²⁹ Among counties in our study that permitted full reopenings of public schools (13), 84.62% (11) have median household incomes below the study average (\$69 077). When

comparing the three median household income graphs, we see that the data for the full reopening of public schools hover at the low end of median household income compared to the data for partial reopening of restaurants and bars.

What is already known on this subject

To mitigate the spread of COVID-19, governments across the world have mandated complete lockdowns. While an abundance of literature has demonstrated the effectiveness of such closures, little research exists to understand the impact of early reopening policies and assess the risk of transmission it poses to community members.

What this study adds

In our study, we analyzed the 14-day change in infection rate following the reopening of six public business types in 83 US counties. We found significant increases in infection rate following the reopening of bars and gyms, determined that the change of infection rate is dependent on the degree of mask wearing in businesses and noted a positive correlation between the median household income and infection rate following the reopening of restaurants. Our research provides insight into the transmission of COVID-19 and promotes evidence-driven policymaking for disease prevention and community health.

Limitations of this study

While comparing the change in infection rate 14 days after business reopenings, there may be additional variables unaccounted for—such as private in-home gatherings and social events and congregation among co-workers at essential businesses. Nonetheless, the public businesses in this study account for many human-to-human interactions that likely contributed to changing infection rates. Another limitation of this study was that we did not account for reclosures following the first partial reopening of businesses; some local governments mandated multiple reclosures and reopenings due to fluctuating growth rates of COVID-19. Finally, in the case of the change of mobility data, not all variables could be analyzed at the county-level.

Conclusion

Based on 83 counties, we deduced that, on average, partially and fully reopening public businesses after a period of lockdown increases the overall infection rate among counties. When businesses partially reopen, the rise of infection rate is largest for bars (followed by gyms) and the lowest for retail. When businesses fully reopen, the rise of infection rate is largest for gyms (followed by salons/barbers) and

the lowest for bars. When comparing other factors to the change in infection rate, mask usage plays a substantial role in curtailing/rising infection rates when restaurants and bars reopen. Median household income also correlates with changing infection rates following restaurant and public school reopenings. This research provides insight into the influence of specific reopenings on the spread of COVID-19 and encourages data-motivated policymaking for the COVID-19 pandemic as well as for future pandemics.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Role of funding sources

Funding sources were not involved in the design of the study, the collection of the data, the statistical or formal analysis of the data, the writing of the research article nor the submission of the research article for publication.

Authors' contributions

All authors have made significant contributions toward the completion of this project. All authors have reviewed the final manuscript. A.B. and A.M. took care of the conceptualization, data curation, investigation, formal analysis and writing—original draft preparation. A.M. took care of the software implementation for regression analysis. A.B. was responsible for data visualization and generation of summary tables and figures. R.G. and M.L.R. took care of the methodology. M.L.R. was in charge of validation. R.G., M.L.R. and D.D. took care of writing—reviewing and editing. D.D. was in charge of the supervision.

Ethical approval statement

Ethical approval was not acquired nor applicable for this research article. No human or animal participants were involved in the study. Publicly available data were used in the process of this study.

Supplementary data

Supplementary data are available at the *Journal of Public Health* online.

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Data availability statement

The closing/reopening dates of public business can be found in the online supplementary material. The infection rate data is available upon reasonable request. The county mask use frequency data are available at: <https://github.com/nytimes/covid-19-data/tree/master/mask-use>. The median household income data are available at: <https://data.ers.usda.gov/reports.aspx?ID=17828>. The county population density data are available at: <https://covid.cdc.gov/covid-data-tracker/#county-view>. The change in mobility by state data are available at: <https://covid19.healthdata.org/united-states-of-america?view=infections-testing&tab=compare&test=infections>.

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