Limited impact of lifting universal masks on SARS-COV-2 transmission in schools: The crucial role of outcome measurements

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Word count: (Abstract: 122)

(Main text: 1148)

ABSTRACT

As the pandemic's dynamics changed, many municipalities lifted face wearing requirement in school which was initially implemented to mitigate the transmission of COVID-19. This study examines the effects of lifting mask mandates on COVID-19 transmission within Massachusetts school districts. We first replicated previous research by Cowger et al. (2022) utilizing a Difference-in-Difference (DID) model. Then, we back project the case infection and calculate the Rt value to redo the DID analysis. However, when shifting the outcome measurement to the reproductive number (Rt), our findings suggest that lifting mask mandates can only significantly influence the Rt first two weeks post-intervention. This implies that while mask mandate plays a role in mitigation, its lifting does not drastically influence COVID-19 transmissibility in the long term.

INTRODUCTION

Non-pharmaceutical interventions (NPIs) have played a critical role in reducing transmission during the COVID-19 pandemic and "flattening the curve", spreading out infections over a longer period of time to reduce pressure on healthcare systems. One such NPI, recommending or even requiring people to wear face masks in certain settings or locations, was commonly used during the COVID-19 pandemic. Although challenges exist in examining the effectiveness of face masks in preventing disease transmissions that caused by the heterogeneity in mask materials, inconsistency in user compliance and the coincidental implementation of other NPIs, it was later suggested to be effective in mitigating COVID-19 transmissions and adopted by schools (Boutzoukas et al., 2022; Kim et al., 2020; Sharma et al., 2020). As the pandemic progresses, many local authorities relaxed mask mandates during periods when the pandemic appears to be receding, while the impact of lifting these mandates on transmission remains under-investigated. It's critical to understand both the potential reduction in transmission when a mask mandate is introduced, as well as the possible increase in transmission when such interventions are relaxed or removed.

Cowger *et al.* found significantly lower incidence in schools which maintained universal masking compared to those without in the subsequent surge after mask mandates were lifted in Massachusetts school in February 2021 (Cowger et al., 2022), However, the outcome measurement (i.e., incidence) alone cannot fully reflect the transmission process since it does not account for the exponential changes in case numbers during the transmission. For instance, initial incidence discrepancies between two locations can magnify over time, even if the reproductive number remains constant. Similar oversights of transmission outcomes have been identified in studies about effectiveness of other COVID-19 control measures (Auger et al., 2020), which may have impacted the accuracy of the findings and their implications.

In this study, we used the same data source as Cowger *et al.* to examine the impact of outcome measure (i.e., transmission and/or incidence) on the estimated effectiveness of lifting masks mandates on COVID-19 transmission. After replicating the original analyses using a difference-in-difference model on incidence rate, we replaced the outcome measurement with the effective reproductive number (Rt). Rt is estimated as the average number of secondary infections resulting from one infected individual, measuring the transmissibility in a population (Nash et al., 2022). The Rt reductions are often used to evaluate the effectiveness of mitigation measures in limiting the virus transmission, with Rt below one indicating non-sustainable transmission under existing measures.

RESULTS

We replicated Cowger et al. (2022) analysis using population-weighted COVID-19 incidence as the outcome measurement in a difference-in-difference model. We analysed data from 70 school districts in Massachusetts, with 46 lifting the mask mandates in the first reporting week (type 1), and 15 and 9 districts lifting in the second (type 2) and third (type 3) reporting week, respectively. Chelsea and Boston retained their mandates (type 4). We only replicated results for students, as data on school staff were not available.

Our replication results were consistent with those reported by Cowger et al.'s. We found that lifting the masking mandates in schools was associated with a notable increase in

COVID-19 incidence across all district types (Figure 2A), with the lowest incidence in type 4 district that did not lifted the mask mandate. We observed an average treatment effect (ATT) of 39.1 (95% CI: 20.4-57.4) COVID-19 cases per 1,000 students associated with lifting masking mandates, compared to 39.9 (95% CI: 24.3-55.4) in the original analysis (Cowger et al., 2022). Analyses using incidence as outcomes suggested that lifting the masking mandates in schools was associated with 39.1 additional cases per 1,000 students within a 15-week period (Figure 2C).

We further analysed the impact of lifting masks mandates on changes in Rt, which measures COVID-19 transmission intensity. Rt was estimated using method by Cori *et al.*'s method with a mean serial interval of 4.4 days (standard deviation 3.0 days) (Alene et al., 2021). Contrary to the original results using incidence rates, we found no significant difference in Rt across district types, except for type 4 district, which showed a slightly higher Rt in the first two weeks after lifting the mask mandates (Figure 2B). There was no association between lifting mask mandates and reductions in Rt (ATT 0.04, 95% CI, -0.11 to 0.20) throughout the entire post-lifting period (Figure 2D). Moreover, Rt remained below 1 from February to May, indicating a general decline in the epidemic during that time until a new wave of the pandemic in late April. (Figure 2B).

Sensitivity analysis yielded consistent results when using longer serial intervals (Bi et al., 2020; Xu et al., 2020) (Table S1) and weighting difference-in-difference model with populations (Brantly Callaway, 2022; Callaway & Sant'Anna, 2021) (Table S2). Our difference-in-difference analysis satisfied the parallel trend assumption and, according to Cowger *et al.* (2022), other time-varying variables including vaccination rate and community transmission remained stable during the study period.

DISCUSSION

We found no evidence that lifting mask mandates in Massachusetts schools significantly affected COVID-19 transmission rates, which is contrary to the findings reported by Cowger et al. Our findings demonstrate that substantial changes in incidence or case numbers do not necessarily reflect substantial changes in underlying transmission. Additionally, we found non-sustainable transmission (i.e., Rt < 1) across all school districts before masks mandates were lifted, suggesting that factors other than lifting mask mandates impacted COVID-19 transmission in these schools, such as community transmission and the implementation of other measures (e.g., extensive testing) (Braga et al., 2022; Falk et al., 2021; Head et al., 2022; Juutinen et al., 2023).

Our findings highlight the importance of considering transmissibility outcomes when assessing the effectiveness of interventions against disease transmission(Cowger et al., 2022). While as counts-based outcomes (e.g., incidence) can serve as proxies for the difficult-to-measure transmission process, it is crucial to note that nonpharmaceutical interventions work by reducing person-to-person transmission, reducing subsequent incidence from what it would have been without the interventions. Due to exponential case growth and delays in disease development (e.g., incubation periods), changes in case counts may exaggerate and lag changes in transmission. Therefore, caution is necessary when interpreting the effects of interventions based on solely on analyses of incidence rates.

Our study has some limitations. Firstly, we were unable to account for unobserved heterogeneities, such as mask types and compliance with mask mandates. Therefore, our findings reflect the impact of the lifting of masks mandate policies rather than the direct effects of mask-wearing (Gettings et al., 2022; Tupper & Colijn, 2021). Secondly, we only estimated Rt using student cases, and we were unable to account for factors such as transmission between student and staff and external community due to data availability. Consequently, our results may partially capture the within-school transmission dynamics.

In summary, we found limited impact of lifting mask mandates on reducing COVID-19 transmission in Massachusetts schools in February 2021. Future assessments of the effects of interventions against transmission should consider including transmissibility outcomes.

REFERENCES

1. Alene, M., Yismaw, L., Assemie, M. A., Ketema, D. B., Gietaneh, W., & Birhan, T. Y. (2021). Serial interval and incubation period of COVID-19: a systematic review and meta-analysis. *BMC Infect Dis*, *21*(1), 257. https://doi.org/10.1186/s12879-021-05950-x
2. Auger, K. A., Shah, S. S., Richardson, T., Hartley, D., Hall, M., Warniment, A., Timmons, K., Bosse, D., Ferris, S. A., Brady, P. W., Schondelmeyer, A. C., & Thomson, J. E. (2020). Association Between Statewide School Closure and COVID-19 Incidence and Mortality in the US. *Jama*, *324*(9), 859-870. https://doi.org/10.1001/jama.2020.14348
3. Bi, Q., Wu, Y., Mei, S., Ye, C., Zou, X., Zhang, Z., Liu, X., Wei, L., Truelove, S. A., Zhang, T., Gao, W., Cheng, C., Tang, X., Wu, X., Wu, Y., Sun, B., Huang, S., Sun, Y., Zhang, J., . . . Feng, T. (2020). Epidemiology and transmission of COVID-19 in 391 cases and 1286 of their close contacts in Shenzhen, China: a retrospective cohort study. *Lancet Infect Dis*, *20*(8), 911-919. https://doi.org/10.1016/S1473-3099(20)30287-5
4. Boutzoukas, A. E., Zimmerman, K. O., Inkelas, M., Brookhart, M. A., Benjamin, D. K., Sr., Butteris, S., Koval, S., DeMuri, G. P., Manuel, V. G., Smith, M. J., McGann, K. A., Kalu, I. C., Weber, D. J., Falk, A., Shane, A. L., Schuster, J. E., Goldman, J. L., Hickerson, J., Benjamin, V., . . . Benjamin, D. K., Jr. (2022). School Masking Policies and Secondary SARS-CoV-2 Transmission. *Pediatrics*, *149*(6). https://doi.org/10.1542/peds.2022-056687
5. Braga, P. P., Souza, M. S., Oliveira, P. P., Romano, M. C. C., Rocha, G. M., & Gesteira, E. C. R. (2022). Children wearing face masks to prevent communicable diseases:

scoping review. *Rev Paul Pediatr*, *41*, e2021164. https://doi.org/10.1590/1984-0462/2023/41/2021164

6. Brantly Callaway, P. H. C. S. A. (2022). did: Treatment Effects with Multiple Periods and Groups. In (Version R package version 2.1.2 https://cran.r-project.org/web/packages/did/index.html ed.).
7. Callaway, B., & Sant'Anna, P. H. C. (2021). Difference-in-Differences with multiple time periods. *Journal of Econometrics*, *225*(2), 200-230. https://doi.org/10.1016/j.jeconom.2020.12.001
8. Cowger, T. L., Murray, E. J., Clarke, J., Bassett, M. T., Ojikutu, B. O., Sanchez, S. M., Linos, N., & Hall, K. T. (2022). Lifting Universal Masking in Schools - Covid-19 Incidence among Students and Staff. *N Engl J Med*, *387*(21), 1935-1946. https://doi.org/10.1056/NEJMoa2211029
9. Falk, A., Benda, A., Falk, P., Steffen, S., Wallace, Z., & Høeg, T. B. (2021). COVID-19 Cases and Transmission in 17 K-12 Schools - Wood County, Wisconsin, August 31-November 29, 2020. *MMWR Morb Mortal Wkly Rep*, *70*(4), 136-140. https://doi.org/10.15585/mmwr.mm7004e3
10. Gettings, J. R., Gold, J. A. W., Kimball, A., Forsberg, K., Scott, C., Uehara, A., Tong, S., Hast, M., Swanson, M. R., Morris, E., Oraka, E., Almendares, O., Thomas, E. S., Mehari, L., McCloud, J., Roberts, G., Crosby, D., Balajee, A., Burnett, E., . . . Vallabhaneni, S. (2022). Severe Acute Respiratory Syndrome Coronavirus 2 Transmission in a Georgia School District-United States, December 2020-January 2021. *Clin Infect Dis*, *74*(2), 319-326. https://doi.org/10.1093/cid/ciab332
11. Head, J. R., Andrejko, K. L., & Remais, J. V. (2022). Model-based assessment of SARS-CoV-2 Delta variant transmission dynamics within partially vaccinated K-

12 school populations. *Lancet Reg Health Am*, *5*, 100133. https://doi.org/10.1016/j.lana.2021.100133

12. Juutinen, A., Sarvikivi, E., Laukkanen-Nevala, P., & Helve, O. (2023). Face mask recommendations in schools did not impact COVID-19 incidence among 10-12-year-olds in Finland - joinpoint regression analysis. *BMC Public Health*, *23*(1), 730. https://doi.org/10.1186/s12889-023-15624-9
13. Kim, M. C., Bae, S., Kim, J. Y., Park, S. Y., Lim, J. S., Sung, M., & Kim, S. H. (2020). Effectiveness of surgical, KF94, and N95 respirator masks in blocking SARS-CoV-2: a controlled comparison in 7 patients. *Infect Dis (Lond)*, *52*(12), 908-912. https://doi.org/10.1080/23744235.2020.1810858
14. Nash, R. K., Cori, A., & Nouvellet, P. (2022). https://doi.org/10.1101/2022.12.08.22283241
15. Sharma, S. K., Mishra, M., & Mudgal, S. K. (2020). Efficacy of cloth face mask in prevention of novel coronavirus infection transmission: A systematic review and meta-analysis. *J Educ Health Promot*, *9*, 192. https://doi.org/10.4103/jehp.jehp_533_20
16. Tupper, P., & Colijn, C. (2021). COVID-19 in schools: Mitigating classroom clusters in the context of variable transmission. *PLoS Comput Biol*, *17*(7), e1009120. https://doi.org/10.1371/journal.pcbi.1009120
17. Xu, X. K., Liu, X. F., Wu, Y., Ali, S. T., Du, Z., Bosetti, P., Lau, E. H. Y., Cowling, B. J., & Wang, L. (2020). Reconstruction of Transmission Pairs for Novel Coronavirus Disease 2019 (COVID-19) in Mainland China: Estimation of Superspreading Events, Serial Interval, and Hazard of Infection. *Clin Infect Dis*, *71*(12), 3163-3167. https://doi.org/10.1093/cid/ciaa790

ACKNOWLEDGMENTS

This work was financially supported by a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China (Project No. T11-705/21-N).

AUTHOR CONTRIBUTIONS

All authors meet the ICMJE criteria for authorship. The study was conceived by ML, BY and BJC. Data analyses were done by ML. ML and BY wrote the first draft of the manuscript, and all authors provided critical review and revision of the text and approved the final version.

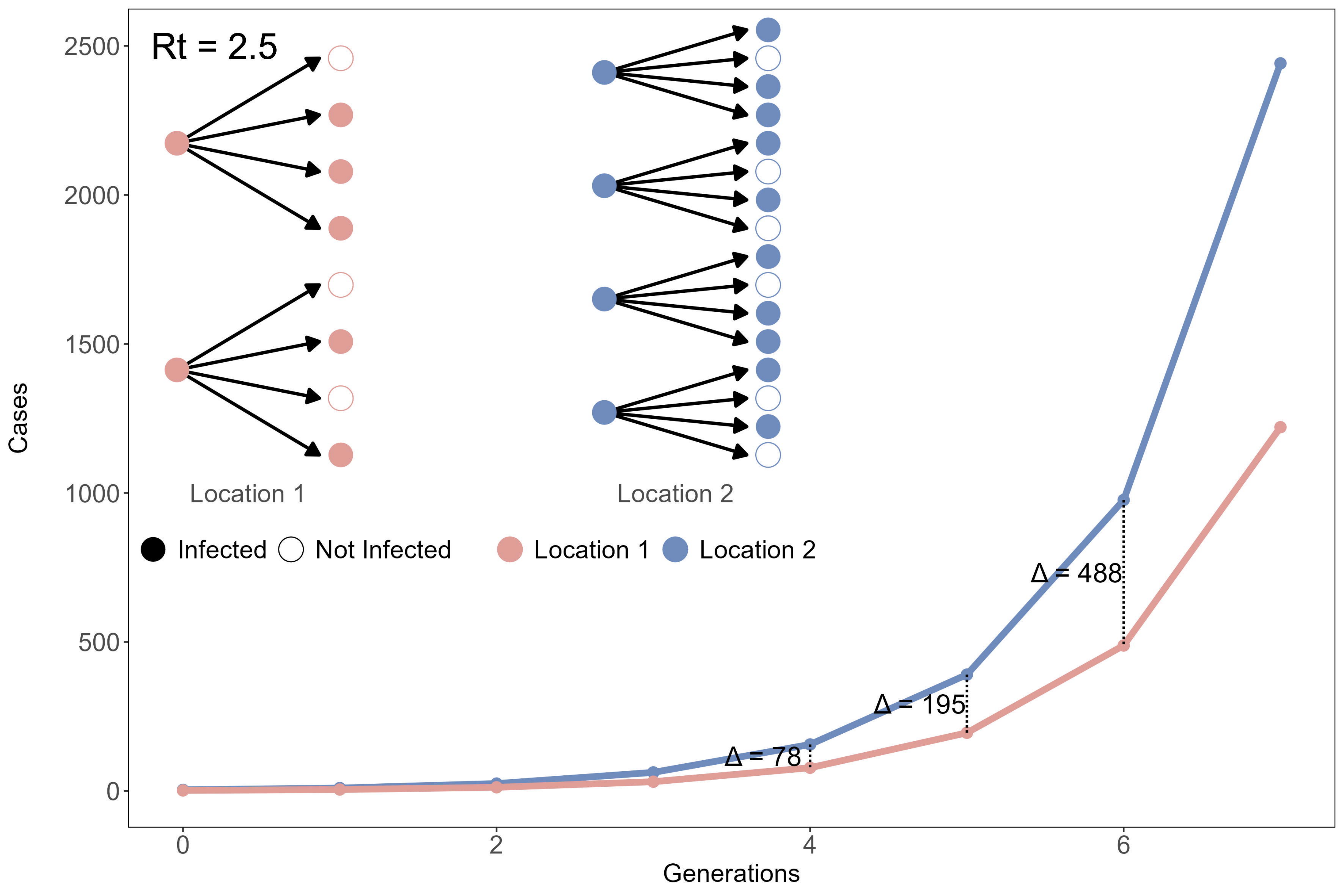
COMPETING INTERESTS STATEMENT

B.J.C consults for AstraZeneca, Fosun Pharma, GlaxoSmithKline, Haleon, Moderna, Novavax, Pfizer, Roche, and Sanofi Pasteur. All other authors report no potential conflicts of interest.

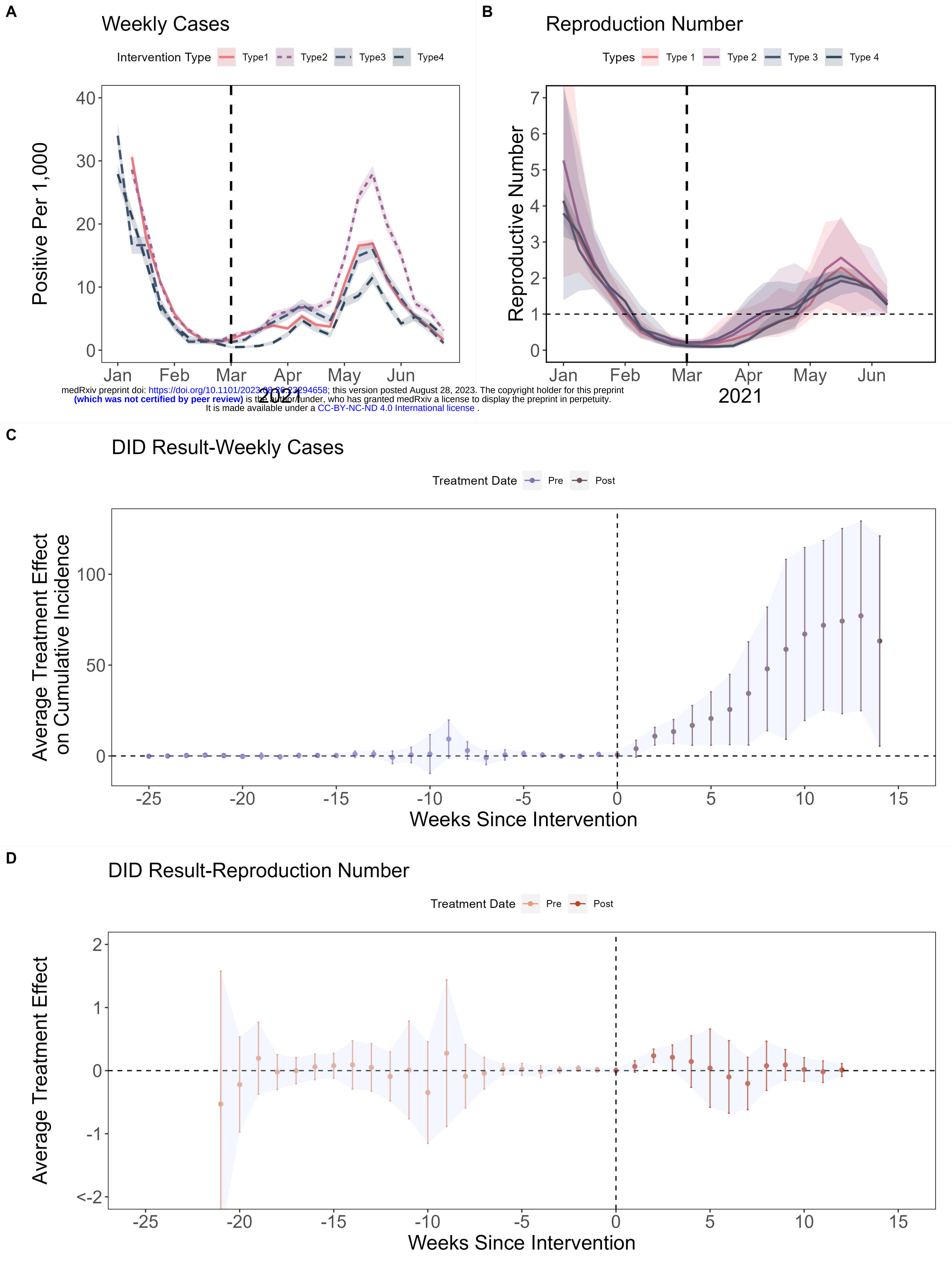
FIGURE LEGENDS

Figure1. Hypothetical Demonstration of epidemic dynamic of 2 locations with identical Rt.

Figure 2. **Difference-in-difference (DID) model analyses of COVID-19 incidence and effective reproductive number (Rt). (A)** Weekly COVID-19 case trend by types of school district. **(B)** Daily COVID-19 Rt estimated from back projected incidence of students, stratified by types of school districts. **(C)** Average treatment effects (ATT) of the lifting masks mandates on cumulative incidence in students. **(D)** Average treatment effects (ATT) of the lifting mask mandates on Rt.



Rt = 2.5
Location 1
Location 2
Infected
Not Infected
Location 1
Location 2
Δ = 488
Δ = 195
Δ = 78
Cases
2500
2000
1500
1000
500
0
0
2
4
6
Generations


A
Weekly Cases
Intervention Type
Type1
Type2
Type3
Type4
Positive Per 1,000
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
2021
B
Reproduction Number
Types
Type 1
Type 2
Type 3
Type 4
Reproductive Number
7
6
5
4
3
2
1
0
Jan
Feb
Mar
Apr
May
Jun
2021
C
DID Result-Weekly Cases
Treatment Date
Pre
Post
Average Treatment Effect
on Cumulative Incidence
100
50
0
-25
-20
-15
-10
-5
0
5
10
15
Weeks Since Intervention
D
DID Result-Reproduction Number
Treatment Date
Pre
Post
Average Treatment Effect
2
1
0
-1
<-2
-25
-20
-15
-10
-5
0
5
10
15
Weeks Since Intervention