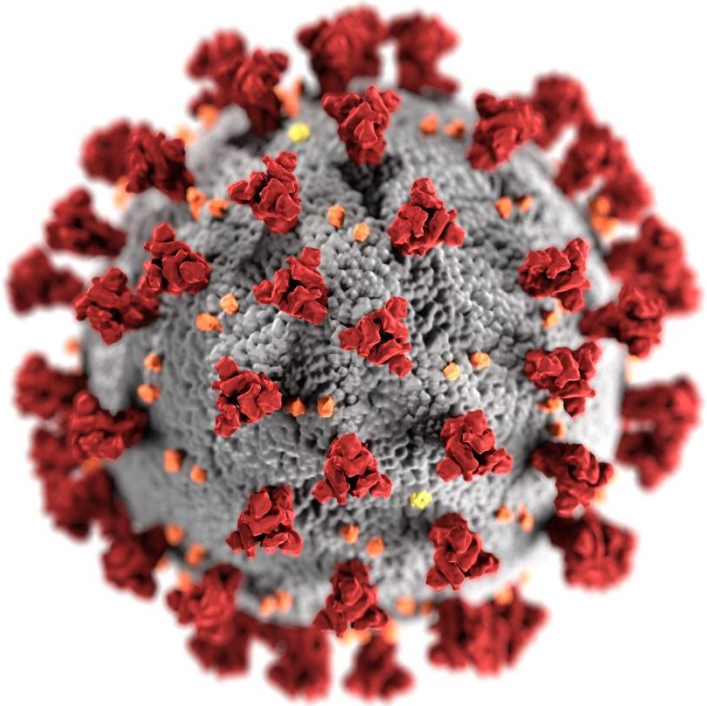
The Science of Masking to Control COVID-19



cdc.gov/coronavirus

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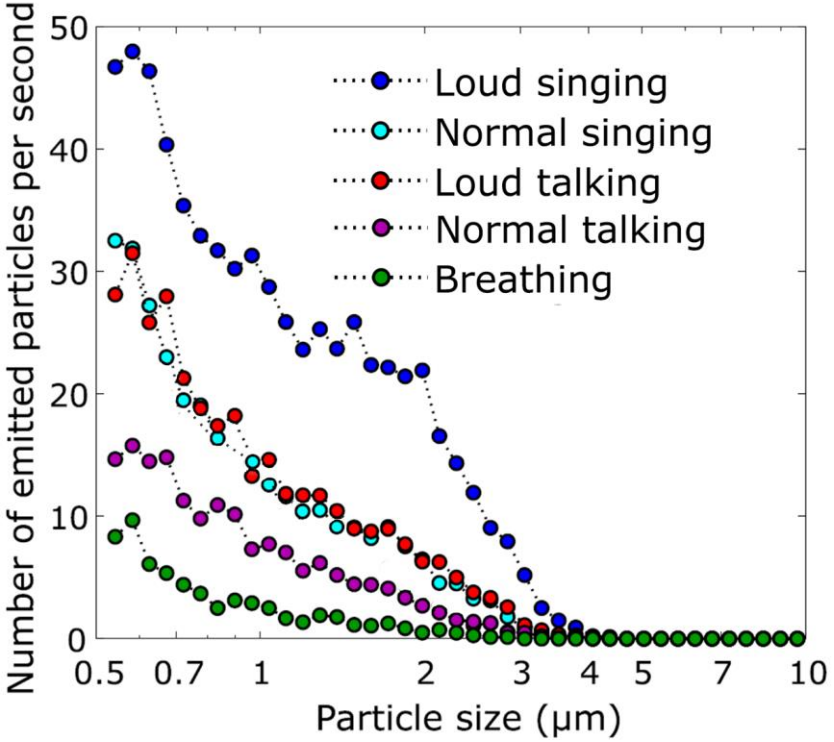
Most SARS-CoV-2 Infections Are Spread by People without Symptoms



Infection is spread primarily through exposure to respiratory droplets exhaled by infected people when they breathe, talk, cough, sneeze, or sing

- Most of these droplets are <10 μm, often referred to as aerosols
- The amount of these fine droplets and particles increases with volume of speech (e.g., loud talking, shouting) and respiratory exertion (e.g., exercise)

Adapted from Aslved et al. 2020, Aerosol Sci Technol; https://doi.org/10.1080/02786826.2020.1812502.

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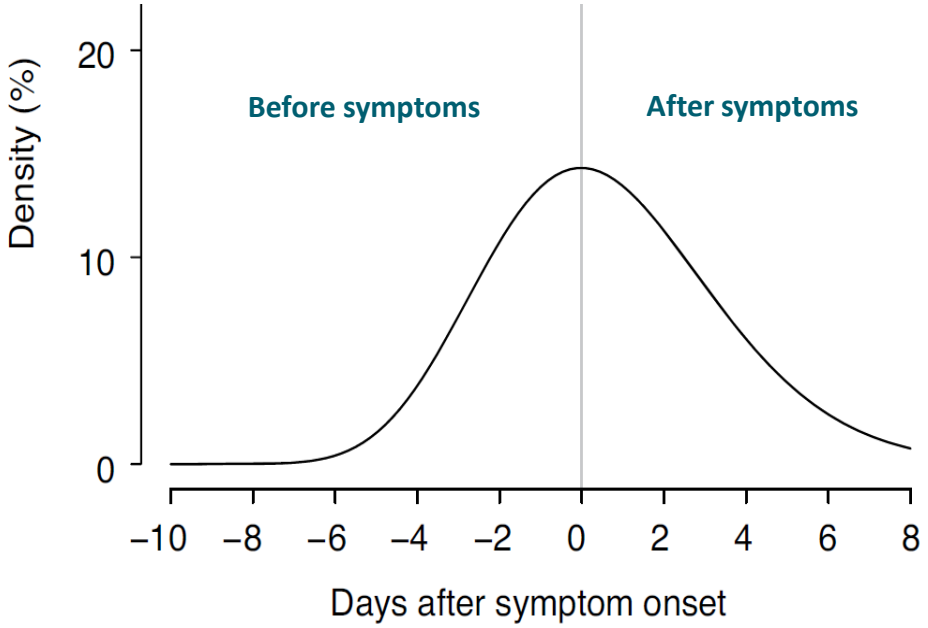

- 40-45% of infected people are estimated to never develop symptoms
- Among people who do develop symptomatic illness
  - Transmission risk peaks in the days just before symptom onset (presymptomatic infection) and for a few days thereafter
  - Accordingly, the number of infections transmitted peaks when virus levels peak

He et al. 2002, Nat Med; 26(5):672-675 and 26(9):1491-1494.

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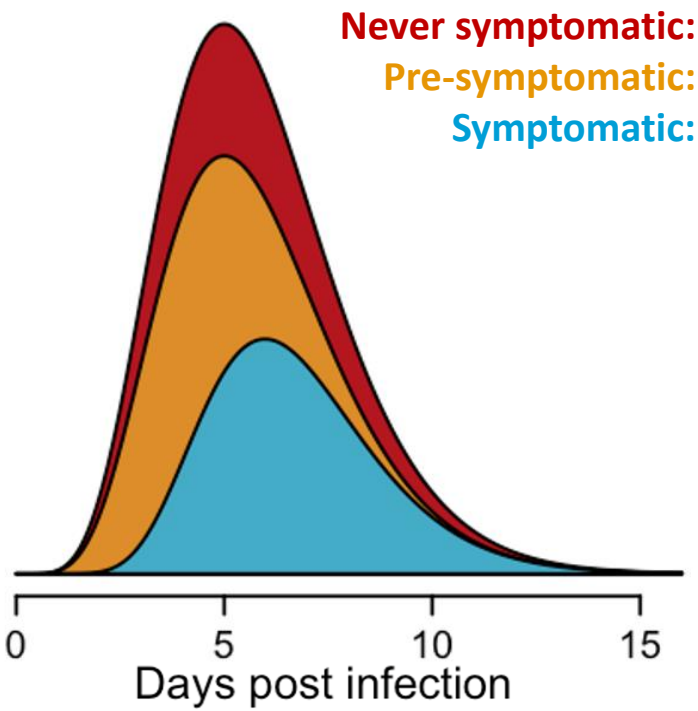
Most SARS-CoV-2 Infections Are Spread by People without Symptoms



- CDC and others estimate that more than 50% of all infections are transmitted from people who are not exhibiting symptoms
- This means, at least half of new infections come from people likely unaware they are infectious to others (red and orange in the figure, left)*

* Figure assumes peak infectiousness occurs 5 days after infection and that 24% of infections are asymptomatic. With these assumptions, 59% of infections would be transmitted when no symptoms are present but could range 51%-70% if the fraction of asymptomatic infections were 24%-30% and peak infectiousness ranged 4-6 days.

Moghadas et al. 2020, Proc Natl Acad Sci USA;117(30):17513-17515. Johansson et al. 2020, CDC unpublished data; submitted.

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Three Levels of Scientific Evidence Demonstrate the Benefit of Community Masking to Control SARS-CoV-2

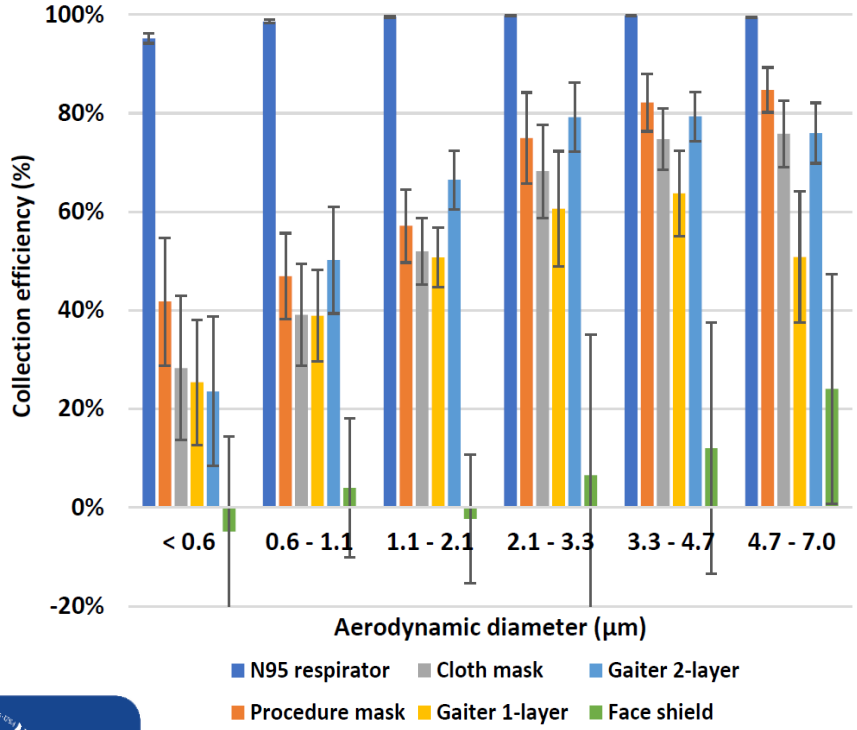
1. Controlled laboratory-based experimental studies of cloth masks' capacity to
   - Block exhaled emission of virus-laden respiratory particles (source control)
   - Reduce inhalation of these droplets by the wearer (personal protection)
2. Epidemiological investigations
   - Outbreaks
   - Cohort and case-control studies
3. Population-level community studies
   - Across multiple levels (e.g., hospital system, city, state, country, multi-country)

Community Masking to Control SARS-CoV-2

Experimental Studies

Valid as of November 16, 2020

Laboratory Assessment of Cloth Masks Effectiveness: Source Control (exhalational)



Cloth masks provide source control

- Cloth masks block most large (>20-30 µm) exhaled respiratory droplets
- Multi-layer cloth masks substantially block respiratory droplets <1-10 µm
  - Comprise the greatest fraction of exhaled respiratory droplets
  - Reductions as high as 50-70%
- Some on par with surgical masks

Figure from Lindsley et al. 2020; medRxiv: doi 10.1101/2020.10.05.20207241.. See "Appendix" at end of slide set for full set of references.

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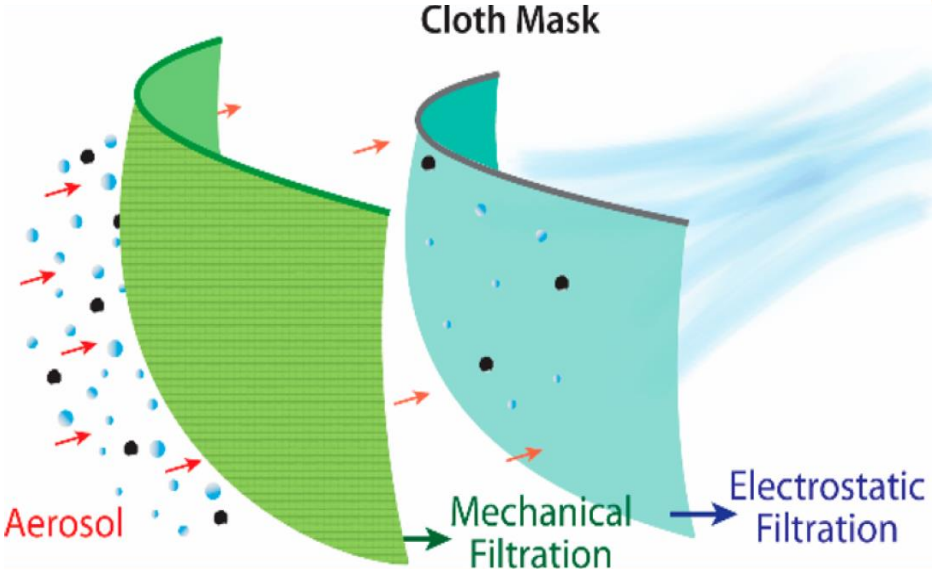
Laboratory Assessment of Cloth Masks Effectiveness: Filtering Protection (inhalational)

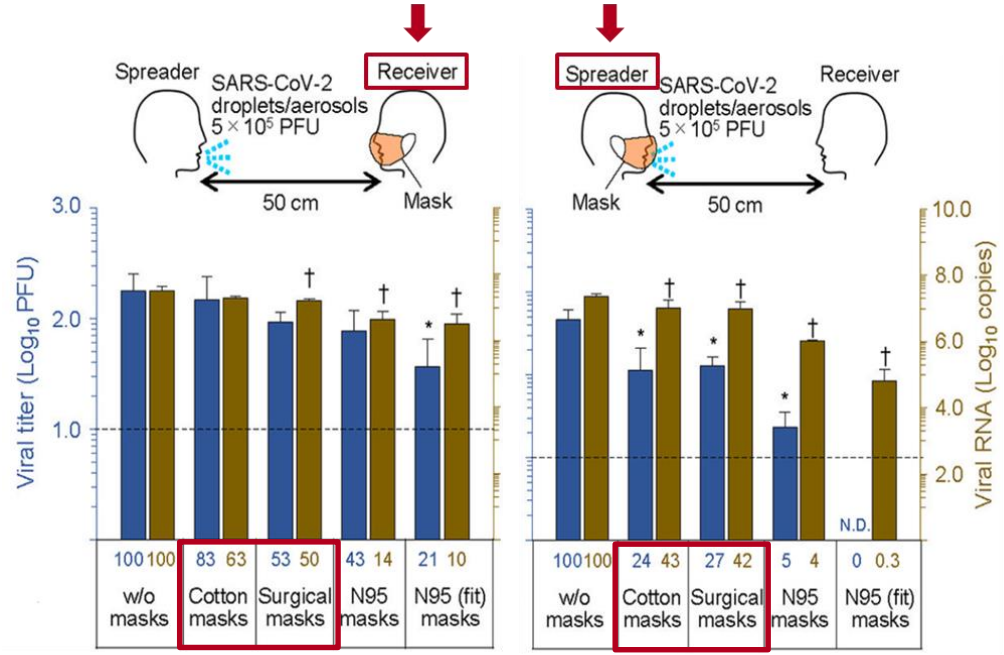


Cloth masks also filter inhaled droplets

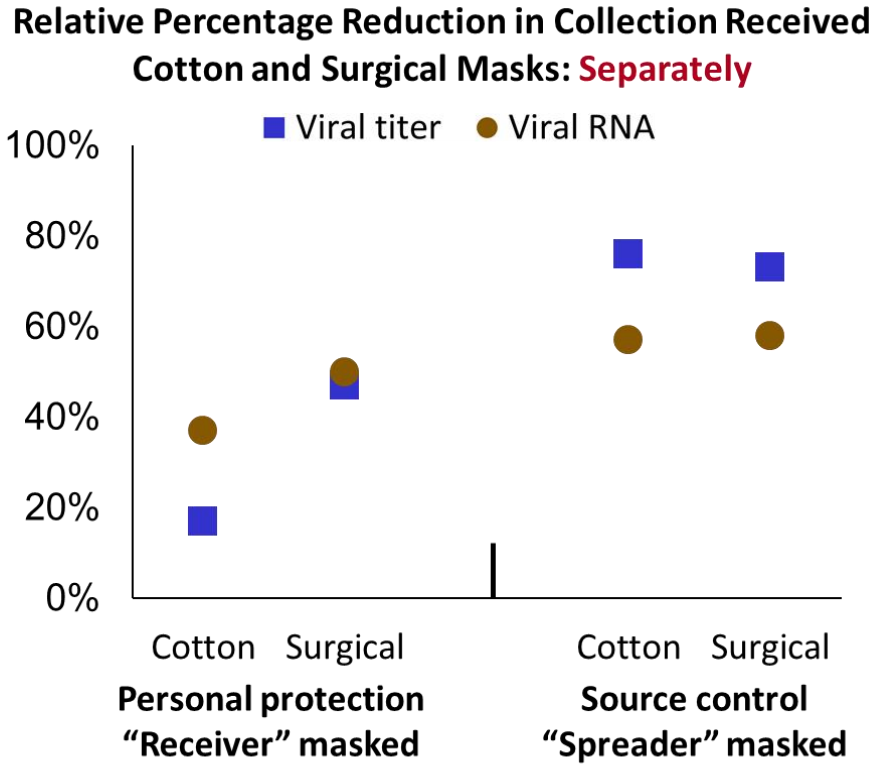
- Their performance *filtering inhaled* small droplets is not as good as their performance *blocking exhaled* small droplets
- Improvements possible with more layers, multiple materials
  - Static charge, hydrophobic
- Opportunities for innovation

Image from Konda et al. 2020, ACS Nano; 14(5):6339-6347. See "Appendix" at end of slide set for full set of references.

Laboratory Assessment of Cloth Masks Effectiveness: Two-Headed Experimental Masking Evaluation using SARS-CoV-2



The numbers below the bars show the percentages detected relative to the left-most control bar values. * and † indicate p-value <0.05 compared with left-most columns.



Ueki et al. 2020, mSphere; doi.org/10.1128/mSphere.00637-20.

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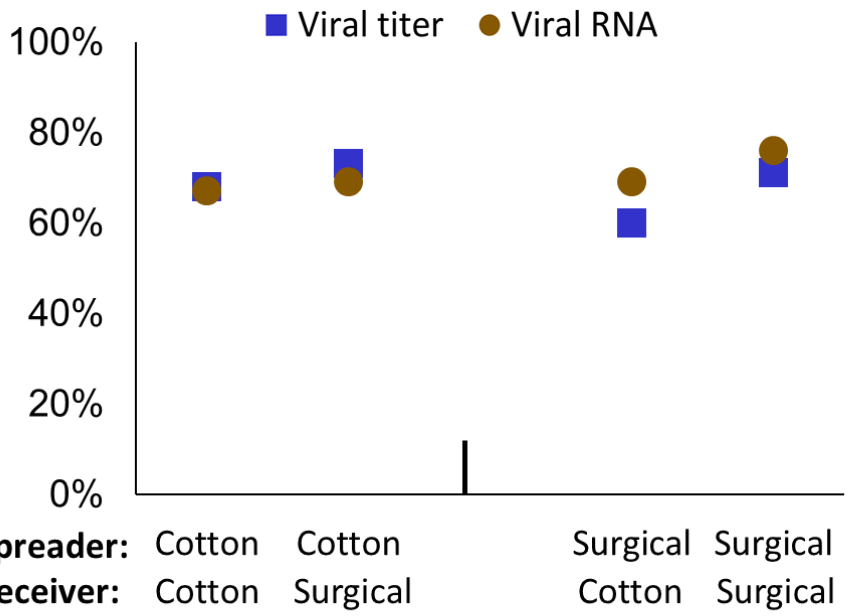
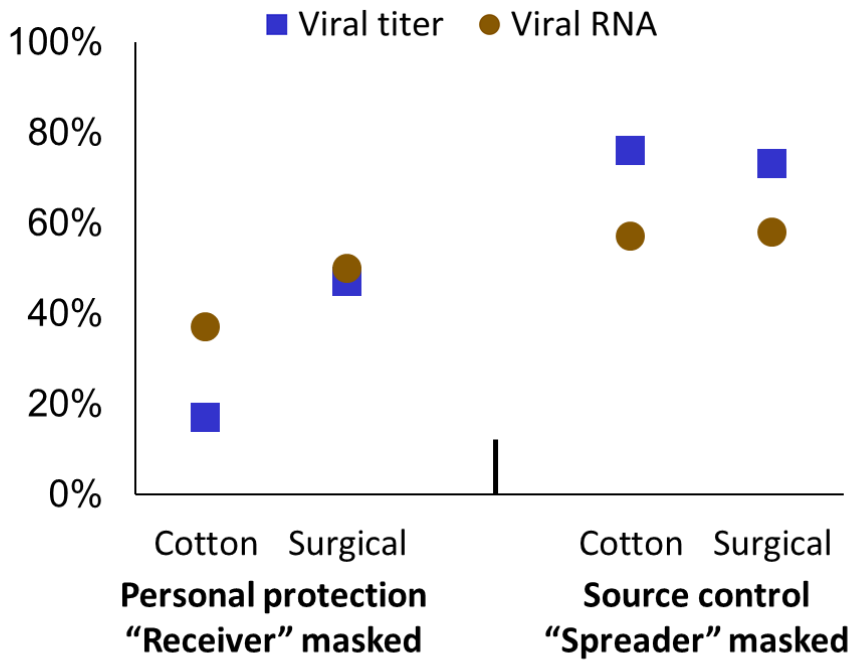
Laboratory Assessment of Cloth Masks Effectiveness: Two-Headed Experimental Masking Evaluation using SARS-CoV-2

Relative Percentage Reduction in Collection Received Cotton and Surgical Masks: Combined



Relative Percentage Reduction in Collection Received Cotton and Surgical Masks: Separately



Ueki et al. 2020, mSphere; doi.org/10.1128/mSphere.00637-20.

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Laboratory Assessment of Cloth Masks Effectiveness: Summary

- Focus on the *relative* effects, not the absolute values from these laboratory studies
  - All experiments are proxies for human experience and biological processes
- Source control is substantial, but there is also measurable and meaningful personal protection with the use of cloth masks
  - Masking reduces the wearers' viral exposure
- Cloth masks are comparable to surgical masks when used together for community control (i.e., when combined for both source control *and* personal protection)

Community Masking to Control SARS-CoV-2

Epidemiological Investigations

Valid as of November 16, 2020

Multiple Epidemiologic Investigations of Cloth Mask Effectiveness

- **High-risk exposure events**
  - May 2020: 2 symptomatically ill hair stylists
    - Interacted closely, for 15 minutes on average, with 139 clients over an 8-day period
    - The stylists and all clients wore masks per local ordinance and company policy
    - *0 of 67 clients subsequently reached for interview and tested developed infection*
  - March and April 2020: Outbreak aboard the USS Theodore Roosevelt
    - Environment notable for congregate living quarters and close working environments
    - *Use of face coverings on-board was associated with a 70% reduced risk*
- **Retrospective case-control study of exposed contacts (Thailand)**
  - March 2020: People who reported having always worn a mask during high-risk exposures
    - Experienced a *greater than 70% reduced risk of acquiring infection* compared with people who did not wear masks under these circumstances

Hendrix et al 2020, MMWR; doi.org/10.1101/2020.05.22.20109231. Payne et al. 2020, MMWR; 69(23):714-721.
Doung-Ngern et al. 2020, Emerg Infect Dis;26(11).

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Multiple Epidemiologic Investigations of Cloth Mask Effectiveness

- **Household surveys**
  - February and March 2020: Within 124 Beijing households with ≥ 1 laboratory-confirmed case of SARS-CoV-2 infection
    - Mask use by the index case and family contacts before the index case developed symptoms *reduced secondary transmission within the households by 79%*
- **Air travel**
  - January 2020: symptomatically ill person was the sole air passenger wearing a surgical mask
    - 15-hour flight (Wuhan to Toronto)
    - *0 of 25 close contacts were infected in subsequent 14 days*
  - June and July 2020: At least 6 known infected passengers on 5 flights
    - 11-hour flights (Dubai to Hong Kong)
    - 100% enforced mask mandate on-board
    - *0 new infections among other passengers in the subsequent 14 days*

Schwartz et al. 2020, CMAJ; 192(15):E410. Freedman et al. 2020, J Travel Med; doi: 10.1093/jtm/taaa178.
Wang et al. 2020, BMJ Glob Health; 5:e002794. doi:10.1136/bmjgh-2020-002794.

Frequently Cited Study that Cloth Masks Are Not Protective

- **MacIntyre et al. 2015: 1,607 healthcare workers in 15 Vietnamese hospitals**
  - Compared: Regular use of surgical masks (3-ply), regular use of cloth masks (2-ply), control (standard masking practice)
  - Endpoint: Respiratory illness identified through self-monitoring or lab-confirmed infection with flu, rhinovirus, or human metapneumovirus
  - Outcome: Despite equal compliance wearing surgical and cloth masks, cloth masks were statistically no better than the control situation and inferior to surgical masks against
    - Clinical upper respiratory illness
    - Lab-confirmed viral infection

MacIntyre et al. 2015, BMJ Open; 5:e006577, doi:10.1136/bmjopen-2014-006577.

Frequently Cited Study that Cloth Masks Are Not Protective

- **Generalization of these findings to community masking is limited**
  - Study did not include SARS-CoV-2 infection
  - Study did not include a true “no mask” group
  - Study took place in a healthcare setting and not a general community setting
  - Hospitalized patients and other staff were not masked (limited source control)
  - Assignment to study arms was unblinded
    - Possible mask-type preferences could influence self-reporting of illness
  - Cloth masks were washed by users and re-used (risk of self-inoculation handling mask)
    - Re-analysis of the data in 2020 found increased risk of infection from self-washing masks
      - HR of infection for self-washing was 2.04 (95% CI 1.03-4.00); p=0.04
    - *“Healthcare workers whose cloth masks were laundered in the hospital laundry were protected as well as those who wore disposable medical masks.” MacIntyre et al., 2020*

MacIntyre et al. 2020, BMJ Open ;10:e042045, doi:10.1136/bmjopen-2020-042045.
MacIntyre et al. 2015, BMJ Open; 5:e006577, doi:10.1136/bmjopen-2014-006577.

Community Masking to Control SARS-CoV-2

Community Studies

Valid as of November 16, 2020

Jurisdictional Declines in New Diagnoses Associated With Organizational/Political Leadership Directives for Universal Masking

- Seven published reports examined changes in new diagnoses or deaths with mask mandates
  - Massachusetts General Brigham (MGB) Integrated Health Care System
  - Jena city, Germany
  - Arizona state, United States
  - 15 states and District of Columbia, United States (two analyses)
  - Canada, national
  - United States, national
- All observed reductions in new COVID-19 diagnoses (n=6) or deaths (n=3) following recommendations for universal masking

Wang et al. 2020, JAMA; 323(14):1341-1342. Gallaway et al 2020, MMWR; 69(40):1460-1463. Lyu and Wehby 2020, Health Affairs (Millwood); 39(8):1419-1425.
Mitze et al. 2020, Institute of Labor Economics Report; DP No. 13319, http://ftp.iza.org/dp13319.pdf.
Karaivanov et al. 2020, National Bureau Of Economic Research; Working Paper 27891, http://www.nber.org/papers/w27891.
Hatzius et al. 2020, Goldman Sachs Research report https://www.goldmansachs.com/insights/pages/face-masks-and-gdp.html.
Chernozhukov et al. 2020, medRxiv: https://doi.org/10.1101/2020.05.27.20115139.

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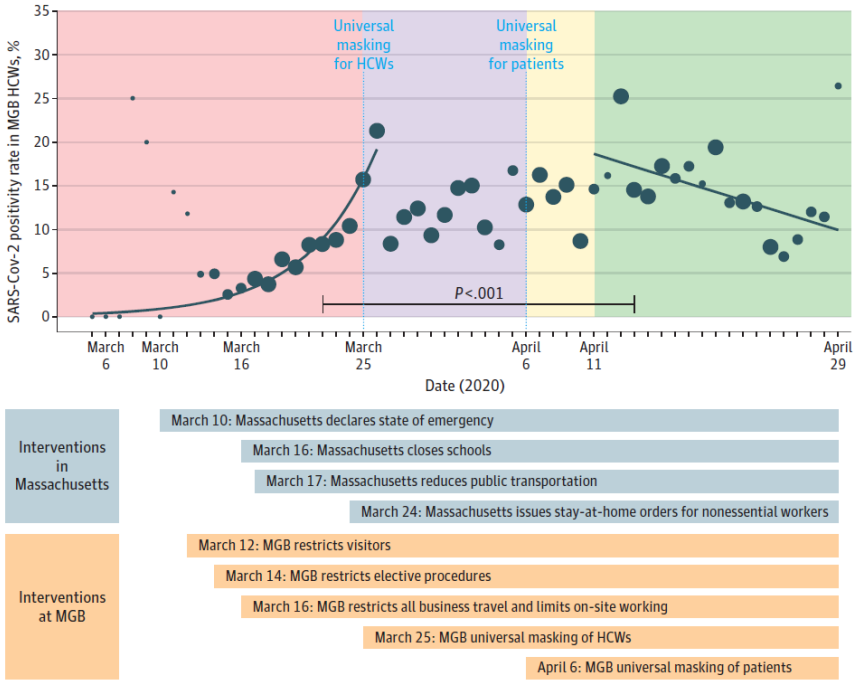
Jurisdictional Declines in New Diagnoses Associated With Organizational/Political Leadership Directives for Universal Masking

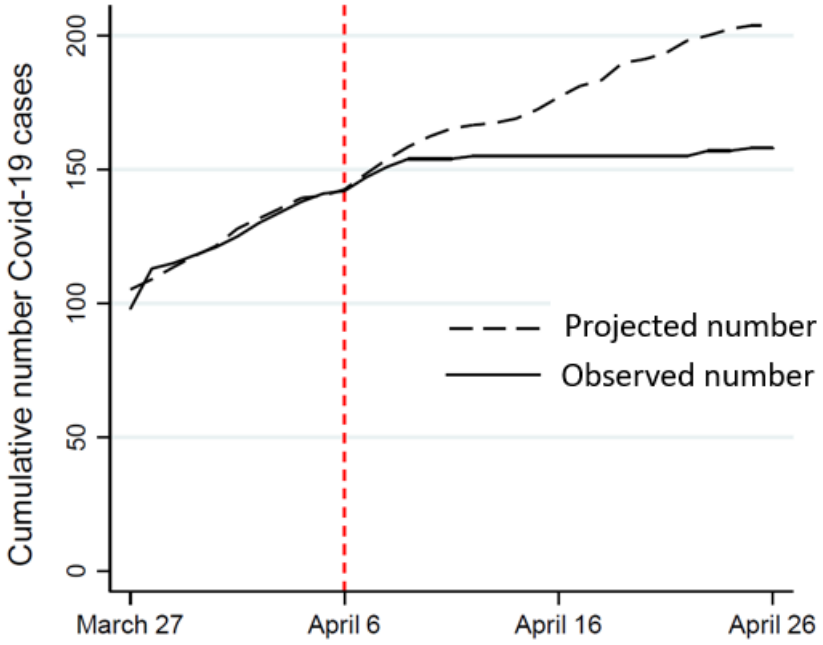


- MGB required masking for all health care workers (HCW) followed two weeks later by required masking for all patients and visitors
- Despite interventions locally and within the MGB system (see bars below figure)
  - New diagnoses among HCWs first started to decline within ~1 week* after implementation of full masking mandate

* Median incubation period is 4-6 days

Wang et al. 2020, JAMA; 324(7):703-704. doi:10.1001/jama.2020.12897

Jurisdictional Declines in New Diagnoses Associated With Organizational/Political Leadership Directives for Universal Masking



- Political leaders mandated universal community masking in the city of Jena (Germany) on April 6, 2020
- New diagnoses leveled off starting about 10 days later*
- Cumulative decline in number of new diagnoses of about 25% within 20 days
  - >50% for persons aged ≥ 60 years
- Other interventions had already been introduced (e.g., social distancing, hand hygiene)

* Median incubation period is 4-6 days

Adapted from Mitze et al. 2020, Institute of Labor Economics Report; DP No. 13319, http://ftp.iza.org/dp13319.pdf.

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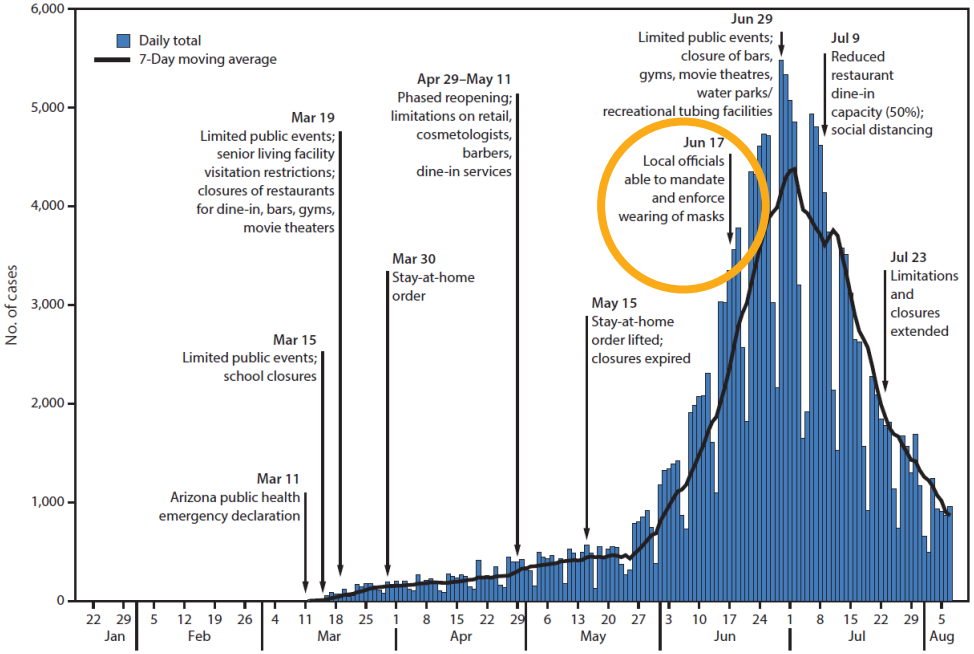

- Arizona mandated masking on June 17
- Decline in number of new cases began about 12 days later*
- Further interventions applied June 29
  - These interventions were coincident with the start of the decline
  - Their effect could not have been instantaneous
  - This observation suggests start of decline was due to earlier masking mandate

Gallaway et al. 2020, MMWR; 69(40):1460-1463.10.15585/mmwr.mm6940e3.

* Median incubation period is 4-6 days

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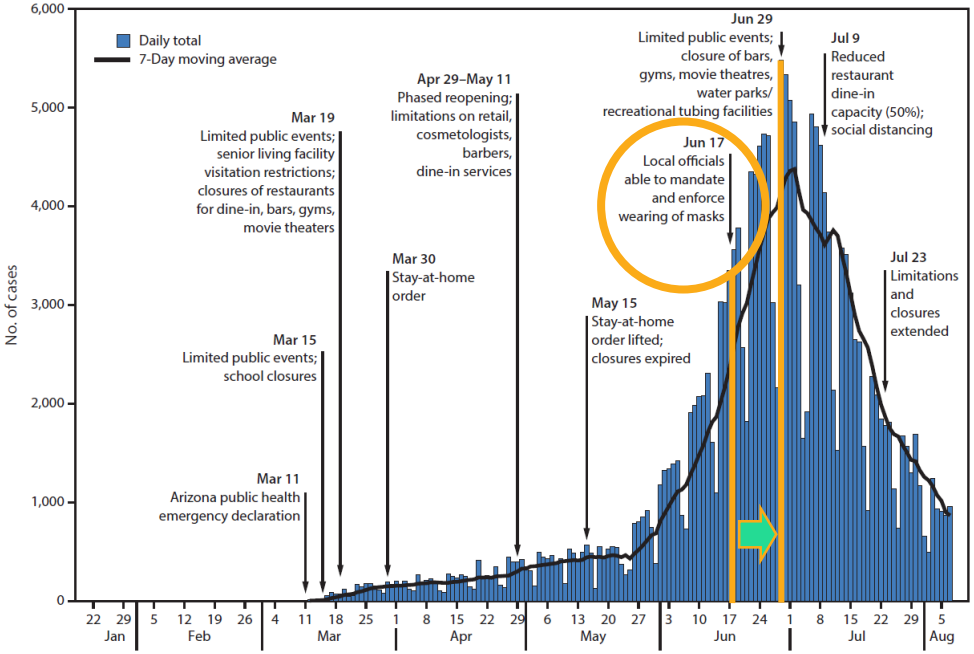
Jurisdictional Declines in New Diagnoses Associated With Organizational/Political Leadership Directives for Universal Masking



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* Median incubation period is 4-6 days

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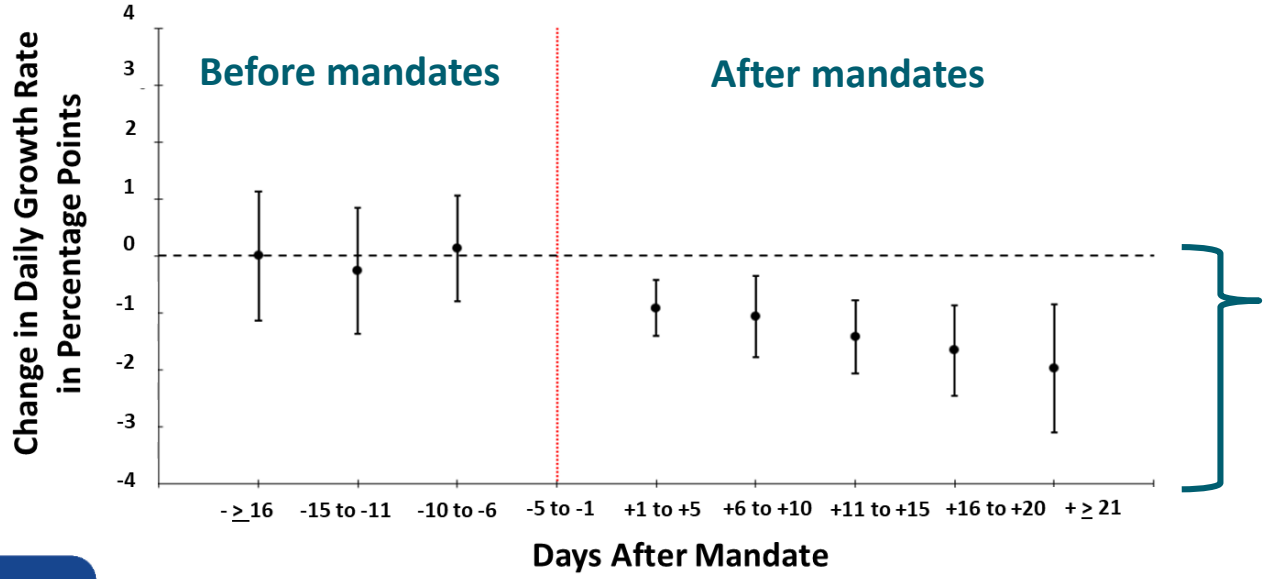
Jurisdictional Declines in New Diagnoses Associated With Organizational/Political Leadership Directives for Universal Masking

- Masking mandates in 15 states led to 2% decline in rate of new diagnoses by 21 days*
- Rate of decline steadily increased with time after mandate, doubling by 21 days



Daily decline in rate of new cases grew larger the longer the mandates were in place

Lyu and Wehby 2020, Health Affairs (Millwood); 39(8):1419-1425.

*included D.C. and controlled for other major COVID-19 mitigation policies as time-varying.

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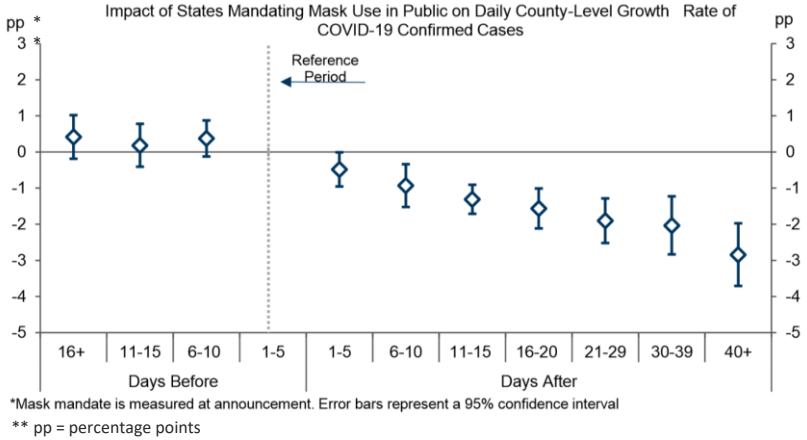
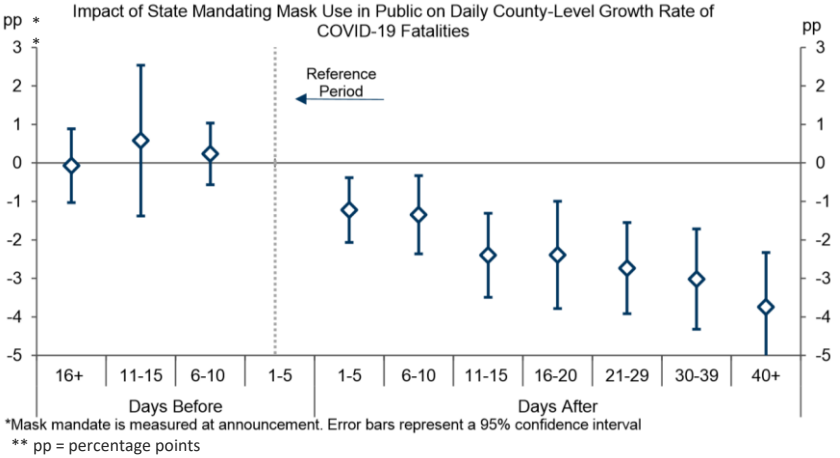
Jurisdictional Declines in New Diagnoses Associated With Organizational/Political Leadership Directives for Universal Masking

- Mandatory masking prevented both infections and deaths; could avert more lockdowns
- With 15% increase in masking, estimated potential GDP savings of $1 trillion (5% GDP)

Daily Average *Case Rate*



Daily Average *Fatality Rate*



Hatzius et al. 2020, Goldman Sachs Research report, https://www.goldmansachs.com/insights/pages/face-masks-and-gdp.html.

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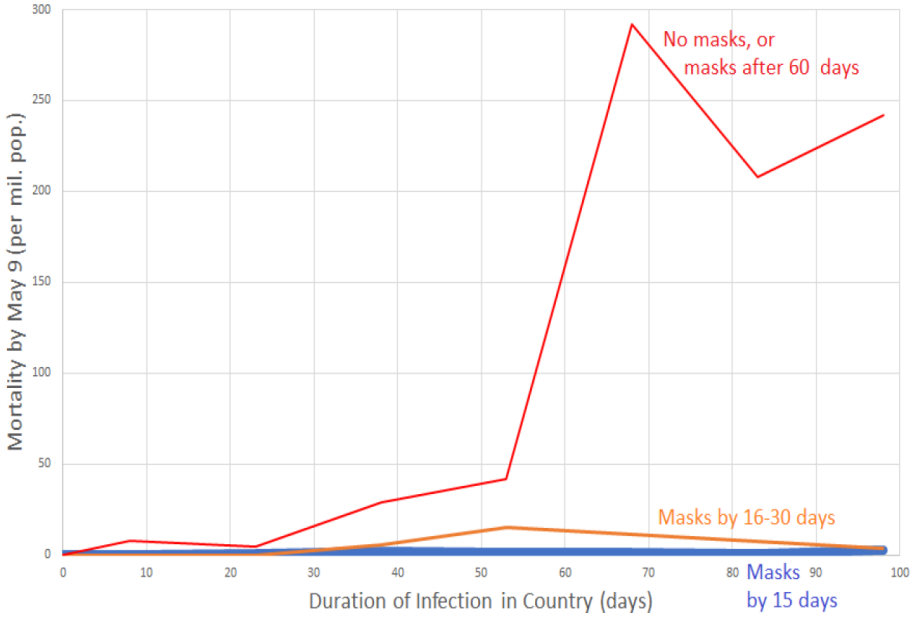
Country-Level Declines in Deaths Associated With Timing of Universal Masking Adoption or Mandates



- Evaluated mortality rates stratified by time
  - From date of first diagnosis to date masking was mandated or otherwise universally adopted in 200 countries (including U.S.) through May 9, 2020
  - Used 3 strata based on time since infection first identified in country
- During each week without masks, mortality increased 59%

Leffler et al 2020, medRxiv; doi.org/10.1101/2020.05.22.20109231.

Valid as of November 16, 2020

The Science of Masking to Control COVID-19: Summary

- **Cloth masks reduce community exposure to SARS-CoV-2**
- **Cloth masks offer both source control and personal protection**
  - The relationship is likely complementary and possibly synergistic
  - Community benefit derives from the combination of these effects
  - Individual benefit increases with increasing community mask use
- **Wearing masks by both the infected and uninfected person gives the uninfected person the most protection**
  - "Masking can protect you and works *best* for *you* when *everyone* does it"
  - "When you wear a mask, you protect others as well as yourself"
- **Universal masking policies can help avert the need for shutdowns**
  - Especially if combined with other non-pharmaceutical interventions such as social distancing, hand hygiene, and adequate ventilation

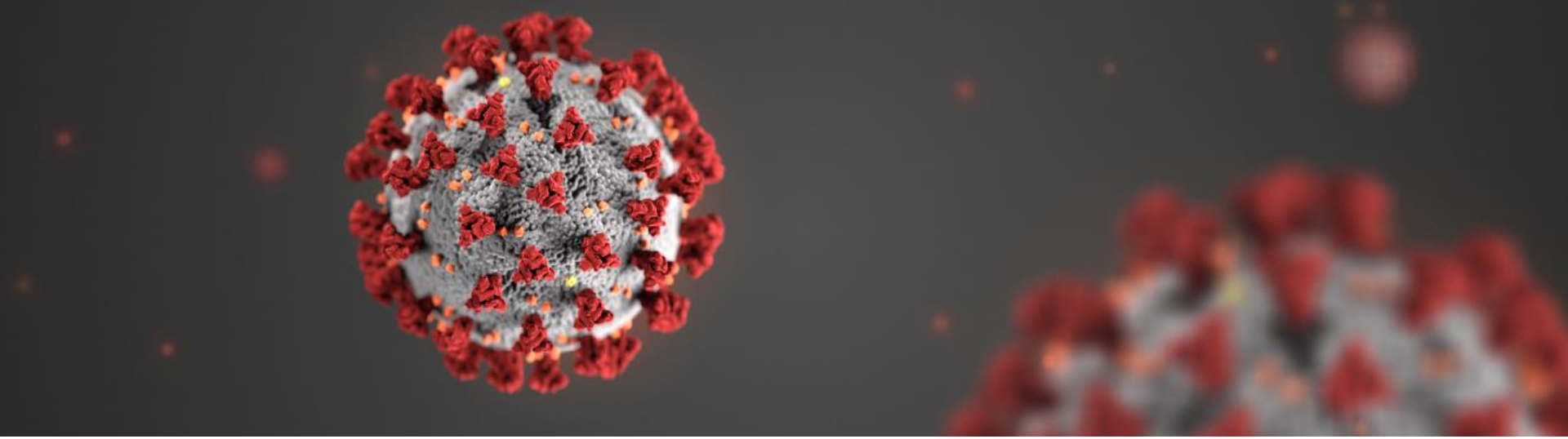
Appendix: Additional References

Slide 7: Laboratory Assessment of Cloth Masks Effectiveness: Source Control

Bandiera et al. 2000, medRxiv; https://doi.org/10.1101/2020.08.11.20145086. Davies et al. 2013, Disaster Med Public Health Prep; 7(4):413-418. Leung et al. 2020, Nature Medicine; 26(5):676-680. Fischer et al. 2020, Sci Adv; 6(36):eabd3083. Lindsley et al. 2020, medRxiv: doi 10.1101/2020.10.05.20207241. Verma et al. 2020, Phys Fluids (1994); 32(6):061708. Alsved et al. 2020, Aerosol Science and Technology; doi 10.1080/02786826.2020.1812502. Asadi et al. 2019, Sci Rep; 9(1):2348. Morawska et al. 2009, J Aerosol Science; 40(3):256-269.Abkarian 2020; Proc Natl Acad Sci; 117(41):25237-25245.

Slide 8: Laboratory Assessment of Cloth Masks Effectiveness: Filtering Protection

Rengasamy et al. 2010, Ann Occup Hyg; 54(7):789-798. Konda et al. 2020, ACS Nano; 14(5):6339-6347. Long et al. 2020, PLoS One; 15(10):e0240499. O'Kelly et al. 2020, BMJ Open; 10(9):e039424. Aydin et al. 2020, Extreme Mech Lett; 40:100924. Bhattacharjee et al. 2020, BMJ Open Respir Res; doi 10.1136/bmjresp-2020-000698. Maurer et al. 2020, J Aerosol Med Pulm Drug Deliv; doi 10.1089/jamp.2020.1635. Hill et al. 2020, Nano Lett; 20(10):7642-7647. Whiley et al. 2020, Pathogens; doi:10.3390/pathogens9090762. Hao et al. 2020, Int J Hyg Environ Health; 229:113582. van der Sande et al. 2008, PLoS One; 3(7):e2618. Chu et al. 2020, Lancet; doi 10.1016/S0140-6736(20)31183-1. Zhao et al. 2020, Nano Lett; 20:5544−5552. Parlin et al. 2020, PLoS One; 15(9):e0239531. Kahler et al. 2020, J Aerosol Sci; 148:105617. Ueki et al. 2020, mSphere; doi.org/10.1128/mSphere.00637-20.



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