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Are We Prepared for The Next Pandemic?

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ABSTRACT

During the COVID-19 pandemic, the world faced an unprecedented level of challenge in attempting to stop the spread of the disease. Now, as progress is continuously made, this current time offers an opportunity to reflect on our management of this pandemic and consider lessons learned for future implications. To investigate which measures were the most effective, I reviewed public health policies, guidance, and their effect on reducing the spread and severity of COVID-19. From this research, I found that the most effective public health measures in curbing widespread transmissions include masking, social distancing, testing, contact tracing, and vaccination. My work proposed specific ways of implementing these existing strategies to improve the management of future pandemic-level disease outbreaks.

Introduction

COVID-19 is an infectious disease caused by the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), first identified in Wuhan, China. Strong evidence indicates that the Huanan Seafood Market was the epicenter of the pandemic, which began in 2019 (Worobey et al., 2022). Under the coronavirus family of enveloped, single-stranded, and positive-sense RNA viruses, SARS-CoV-2 belongs to the genus of Betacoronavirus (β-Cov), which along with the α-Cov genus, can be transmitted from animal to human (Abdelrahman et al., 2020). One of the most distinct characteristics of SARS-CoV-2 is its two-subunit Spike protein (S1 and S2), which plays a crucial role in gaining entry to the host (Huang et al., 2020). Pathways of transmission include inhalation of infected respiratory droplets, ingestion, and transplacental route (WHO, 2020a; Yekta et al., 2021; WHO, 2022a). Specifically, SARS-Cov-2 viral particles can access the mucous membranes through the nose and mouth and enter the respiratory tract. The Spike protein then binds to the human ACE2 receptors, which are abundantly found in the epithelia of the lungs, and enable the virus to enter the cells (Smavati and Uhal, 2020). The primary symptoms of COVID-19 infection include dry cough, fever, sore throat, muscle aches, and other flu-like symptoms. While most individuals have few to no symptoms, some experience severe symptoms and even death. As of August 30th, 2022, there have been at least 601, 462, 351 COVID-19 cases and 6, 488, 069 deaths worldwide (Ritchie et al., 2020). Since the first reported case in Wuhan, China, the COVID-19 pandemic has continued to impact the world with new variants.

However, COVID-19 is not the first pandemic caused by a coronavirus. Two other coronaviruses, SARS-CoV and MERS, have caused a pandemic and epidemic, indicating the propensity of this family of viruses to cause public health crises (Abdelrahman et al., 2020). As such, it is essential for the United States to prepare for the next pandemic and have a clear, actionable response plan to combat its spread. More important than ever, public health policies and preparedness play key roles in our ability to handle global crises as new pathogens and diseases emerge. Below is a discussion of strategies that were proven effective during the COVID-19 pandemic; scientific and epidemiological data are provided to support their use. Following these strategies will likewise offer protection to the public against future coronavirus pandemics.

Face Coverings to Combat Viral Transmission

Mask-wearing remains one of the most effective measures for reducing the transmission of respiratory viruses. When appropriately worn (over the nose and mouth), masks capture infectious respiratory droplets in their fibrous matrix, filtering the air inhaled and exhaled by the wearers (Fleisher et al., 2020). N95 respirators, made of synthetic layers, block 95% of airborne particles (CDC, 2018). Although less effective, surgical and cloth masks still offer some protection; their use should be encouraged, especially during mask shortages, because N95 masks are often reserved for those working in healthcare settings (Chughtai et al., 2020). As concluded by an international meta-analysis, countries with higher use of masks during COVID-19 consistently had lower mortality and infection rates, with an estimated reduction of 56% in infection risk in public spaces alone (Leffler et al., 2020; Liang et al., 2020). In the United States, masking-wearing is suggested to have reduced deaths from COVID-19 by as much as 47%, or close to 50,000 people, between the start of the pandemic to the end of May 2020 (Chernozhukov et al., 2021). Thus, the recommendation for mask wearing is two-fold. *First*, mandated masking should be adopted as early as possible, preferably when cases first emerge. *Next*, masks should be required in healthcare settings and community public spaces, both indoors and outdoors, until transmission risks are extremely low and herd immunity against the virus can offer considerable community protection.

Early Adoption of Masks

Early adoption of mask-wearing is the immediate implementation of masks at the start of an outbreak. This early approach reduces the overall severity of the pandemic by lowering the peak infection, hospitalization, and mortality rates (Howard et al., 2021). In a recent evaluation of worldwide data on policy mandates, the early adoption of mask policies was consistently connected to lower transmission rates of COVID-19 in the short-term and long-term (An et al., 2021). Interestingly, though, mask-wearing has higher public compliance in Asian countries than in Western countries (Leffler et al., 2020). In Germany, researchers used epidemiological data collected in various German cities to show the effects of immediate implementation. They estimated that new cases in a city of 110,000 dropped by 75% during the 20 days after a mask mandate took effect (Mitze et al., 2020). In addition, enforcing mask-wearing early, within 14 days of the first reported cases, strongly correlates with lower mortality rates (An et al., 2021; Leffler et al., 2020). Thus, as these studies show, the early adoption of masks relates to the increased effectiveness of mask policies. Arguably, it may be one of the most cost-effective measures that public health officials can implement to significantly affect the trajectory of a pandemic (Juneau et al., 2022).

Universal Mask Wearing in Healthcare and Public Spaces

Another important factor to consider is the proper time and place for mask-wearing. In healthcare settings, where exposure is the highest, N95 and surgical masks work most effectively at reducing infection risks, as a meta-analysis found that N95 masks lowered the risk by 80% for the wearer (Liang et al., 2020). Hence, medical personnel should certainly adopt their use in hospitals and healthcare facilities, and protocols responding to novel infectious agents in these settings should be enacted at the first signs of a pandemic (WHO, 2020b). For everyday citizens, masks should be worn both indoors and outdoors when in contact with the public. Examples of indoor places where masks should be required include workplaces, grocery stores, shopping centers, and restaurants (though individuals are encouraged to avoid the latter two locations unless necessary). Respiratory droplets ejected from infected individuals can remain suspended in the air for a period ranging from several minutes to several hours and travel distances greater than 6 feet (WHO, 2020a; Howard et al., 2021). Wearing a mask protects individuals from both acute exposure (i.e. in proximity to an infected individual) and suspended viral particles. Generally, indoor spaces have restricted airflow, hence high concentrations of suspended aerosols; therefore, masks are especially important to limiting exposure in these areas.

(Cheng et al., 2021; CDC, 2022b). Though the risk of transmission is lower outdoors, namely due to improved airflow, outdoor gatherings where social distancing protocols were not well observed have been associated with several COVID-19 outbreaks (Majra et al., 2021; Suner et al., 2022). Hence, masks should still be worn at outdoor events where congregations can increase the likelihood of meeting someone with the virus.

Lastly, mask mandates should not be lifted until there is a consistent downward trend in disease incidence and a high level of herd immunity, which is often achieved by a high rate of vaccination in the population.

Physical Distancing

Alongside masking, physical distancing among individuals should be implemented at all times to avoid transmission during close encounters. Respiratory illnesses caused by H1N1, SARS-CoV, and SARS-CoV-2 are primarily transmitted through person-to-person contact; therefore, maintaining distance and avoiding crowded places are crucial to curbing community-level transmission (Strochlic and Champine, 2020; WHO, 2021b; WHO, 2022c). Using an event study model and COVID-19 data collected from Germany, researchers have found that social distancing policies, including physical distancing, significantly lowered the infection and fatality rate compared to a benchmark of no social distancing (Glogowsky et al., 2021). Furthermore, practicing social distancing indoors, by which capacity is lowered to 50%, can reduce indoor transmission risks by 20-40% within the first 30 minutes of exposure if minimal ventilation is used (Sun & Zhai, 2020). When infected or exposed, individuals need to self-isolate or quarantine for the duration of the incubation period, which varies for different viruses, to keep community transmission at a minimum (Howard et al., 2021). However, in many cases, maintaining a social distance of at least six feet is not always possible and hard to enforce. Therefore, physical distancing should work as a necessary complement to masking and other measures rather than as a stand-alone intervention.

Lockdowns as a Last Resort

During the COVID-19 pandemic, many countries have used lockdowns and shelter-in-place orders to control outbreaks (Dunford et al., 2020). Though lockdowns are highly effective at reducing the number of new cases, evidence reveals that nationwide and large regional lockdowns have harmful impacts on the economy, people's health, and existing inequalities (Inoue et al., 2021; Adams-Prassl et al., 2020; Chang et al., 2020). Hence, lockdowns should only serve as a last resort to mitigate the severity of outbreaks. On a broader scale than physical distancing, lockdown measures restrict the interactions and flow of people. Areas where individuals congregate, such as restaurants, cafes, and gyms, should remain closed during times of peak transmission OR have reduced capacity when case numbers are lower. Another key point is that lockdowns targeting smaller locations (i.e., in a specific city or region) can avoid placing an undue burden on other areas whose case numbers are significantly lower. For example, if a superspreader event occurs in a city, a lockdown may be an appropriate local measure to reduce community transmission (Bouffanais & Lim, 2020). Therefore, careful consideration of the timing and spatial targets of lockdowns should precede any enactment. After a lockdown goes into effect, it should be lifted following an area-by-area approach when the incidence becomes sufficiently low (Rawson et al., 2020).

Testing

Alongside restricting movements and person-to-person interactions, identifying and isolating infected individuals as quickly as possible are critical features of any pandemic response; testing is the optimal way to achieve this. For any viral disease, testing is defined as the diagnosis of viral infection either by the detection of viral antigens/genetic material or neutralizing antibodies produced by the host (CDC, 2022b). Currently, the two most prevalent diagnostic tests for SARS-CoV-2 include Polymerase Chain Reaction (PCR) tests and Antigen tests (CDC, 2022b; Schive, 2020).

Early in the COVID-19 pandemic, testing at an effective level in the U.S. was largely unavailable because of the absence of a clear plan and delayed responses (Shear et al., 2020). To effectively utilize testing in future contexts, there are two stages to consider. Under limited availability of tests, individuals who are 1) displaying symptoms, 2) are close contacts of known infected individuals, and 3) healthcare workers and other essential workers should be prioritized for testing. Once available, open public testing (if possible) is the best way to track case numbers and moderate the incidence of viral infections, as many countries did during the COVID-19 pandemic.

Despite evidence showing an elevated risk of SARS-CoV-2 infection for healthcare workers, 42% of registered nurses (RNs) in the U.S. said, in December 2020, that they have never been tested (Nguyen et al., 2020; Wamsley, 2020). The lack of testing was mainly because regulations restricting the test supplies for hospitals were not updated from earlier situations when the main concern had been the overwhelming number of undetected cases in community settings (Wamsley, 2020). Hence, the proper distribution of tests, in addition to test production and availability, is important to maintaining an accurate count of infected persons and addressing needs in a timely manner. Other essential workers, including those in retails, food-processing facilities, security, and transportation, should also have priority because of the high risks associated with their work environments (Krisberg, 2020; Selden & Berdahl, 2021). Likewise, environments with large groups of high-risk populations, including nursing homes and hospital wards, should have priority in routine testing and immediate testing for those displaying symptoms or having known exposure. Once testing is widely available, testing sites should be distributed on large scales, and all persons should receive testing before entering congregated public spaces (i.e. schools, workplaces, restaurants), as prolonged time spent in congregated or enclosed spaces elevate the risk of transmissions (Yechezkel et al., 2021).

Moreover, timely testing can help prevent delays in medical attention and the inundation of ICU units. Through a process of double-testing, South Korea was able to offer quick, accessible testing nationwide and assess and monitor the symptom severity of those who tested positive (Cha, 2022). Individuals with more severe symptoms were able to receive treatments relatively early in the stage of infection; thus, they were prevented from having progressed symptoms or going into the ICU (Robinson et al., 2022).

In brief, testing should be implemented as soon as possible at the start of a pandemic or disease outbreak to prevent widespread transmission, and test supplies should go to those with priority before going to the entire population.

Contact Tracing

Contact tracing, defined as the process of identifying and managing people who have been exposed to someone infected, is a crucial nonpharmaceutical measure in stopping the chain of disease transmission. Working with testing and self-isolation, contact tracing should be implemented as a mitigative measure against outbreaks in community-setting. During the COVID-19 pandemic, almost all countries engaged in some form of contact tracing (Hale et al., 2021). In the U.K., when its contact-tracing system missed 48, 000 close contacts by accident, the number of cases rose from 4. 726 to 21, 149 over three days (Fetzer & Graeber, 2021). In Gwanju, South Korea, contact tracing detected an epidemiologic link connecting 98.6% of the city's COVID-19 cases and, as a result, suppressed an outbreak in a population of 1, 501, 000 (Kang et al., 2021). Here, in the United States, technical issues and other challenges have dampened the effect of contact tracing efforts (Clark et al., 2020).

Direction as a Strategy in Contact Tracing

To make contact tracing more implementable, the direction of tracing close contacts should be based on the transmission characteristic of the virus. In the COVID-19 pandemic, tracing from a potential source outwards and tracing "backward" to a potential source were both used to identify cases and isolate close contacts (Public Health Ontario, 2021). However, evidence suggests that backward tracing in the case of COVID-19 is more effective, as a study cited

a 2-3 times difference in effectiveness between normal contact tracing and backward contacting (Kojaku et al., 2020; Endo et al., 2021). This may be because transmission from COVID-19 is highly variable, meaning that some cases do not infect others, while others can infect an unusually large number of secondary cases (Chen et al., 2021). Therefore, tracing backward from close contacts can help identify more clusters of cases that the primary source had infected (Public Health Ontario, 2021). In future outbreaks, the understanding of the transmission characteristics of a virus will be immensely crucial to determining the most efficient and effective way to contact-trace.

Reaching the Most at Risk

Additionally, reaching out to close contacts based on priority can improve the feasibility of contact tracing. When the number of cases is overwhelmingly high, as experienced by the U.S. and many other Western countries with COVID-19, contact tracers may benefit from focusing on contacts with high risks (i.e. elders, people with underlying conditions, etc.) (WHO, 2022b). Furthermore, if an infected source visited environments with high-risk individuals or high transmission risks, such as nursing homes, health care facilities, and prisons, contact tracers should notify people in these places first. Under limited capacities, this strategy can prevent large outbreaks among high-risk populations and potential delays in receiving adequate treatments (Robinson et al., 2022). Technologies such as mobile tracing apps can aid contact-tracing efforts; however, one notable concern with implementing these technologies is privacy, as individuals' information is shared with the government (McClain & Rainie, 2021). Therefore, making clear regulations on the limits of contact-tracing technologies will support the implantation of such technologies and improve contact tracing efforts.

Vaccination

The development of vaccines was a critical breakthrough in lowering the transmission and saving lives in the COVID-19 pandemic. Currently, there are three types of vaccines against SARS-Cov-2, which are mRNA (e.g. Moderna, Pfizer) vaccines, viral vector vaccines (e.g. Johnson and Johnson), inactivated whole virus vaccines, and protein subunit vaccines (WHO, 2021a; CDC, 2022a). Though the technology differs slightly, these vaccines serve the same purpose of mitigating disease outbreaks and preventing the loss of lives. At the population level, vaccination should have the goal to reach herd immunity. Because vaccines are likely unavailable when a new disease emerges, there can be extremely limited access to supplies at the start of vaccination. The priority of distributing vaccines should then be determined by considering who is the most vulnerable to severe symptoms or death and who plays a significant role in the overall ability to mitigate transmissions. Therefore, in most circumstances, the older population, other persons falling into the high-risk category, and healthcare workers should get vaccinated first. However, there are times when supplies are not even enough to reach all priority groups. Inoculating the elderly (65 years and older) *first* may be the most effective strategy in this scenario. As a study on COVID-19 deaths in the U.S., Germany, and South Korea has found, vaccinating the oldest group within a population first saved the most lives and years of life when the public complied with measures such as social distancing (Goldstein et al., 2021). In South Korea, though the country has been exemplary in controlling COVID-19, it initially lagged behind similar countries in vaccinating its population (Cha, 2022). After vaccines were made available, South Korea chose to target the senior population first, achieving a booster vaccination rate of higher than 90% in those 60 and older in March of 2022 (Cha, 2022). Despite the drastically increasing infection rates during that period, South Korea's case mortality remained one of the lowest worldwide and, as an early study revealed, inoculating the senior group indeed lowered infections (John Hopkins, 2022; Choi et al., 2021). Hence, with limited supplies of vaccines, vaccinating the elderly, especially those living in long-term care facilities, first may serve as an effective approach to future disease outbreaks in the U.S. Once large-scale distributions of vaccines become possible, the vaccination of most of the population should be a top public health priority.

Risk Communication & Trust Building

For any of these public health interventions to reach maximum effectiveness, experts and officials should communicate to the general public, using transparent language, the risks of the disease and the importance of intervening policies. In the U.S., the public has been hesitant, particularly about the use of masks and vaccines. Specifically, the resistance to mask mandates and mask policies starkly contrasts with the high compliance generally seen in Asian countries (Leffler et al., 2020). A meta-analysis found that the high use of masks in Asian countries, even after mandates were lifted, is related to the perceived usefulness and necessity of masks by individuals (Leffler et al., 2020). In fact, before COVID-19, wearing masks in Asia is not an uncommon sight during the winter, as masks policies and public health education efforts during the 1918 H1N1, SARS-CoV, and MERS outbreaks helped normalize masks (Ives, 2022; Rich & Hayashi, 2020; Zhang et al., 2022). Hence, communication and education on part of leaders can tremendously impact the public understanding of the need for specific public health measures, thereby positively influencing public compliance during their implementations. Notably, in the U.S., a significant proportion of Americans show distrust in one or more of the public health measures used during the pandemic (Funk et al., 2022). Thus, trusting building in the general public is a critical factor to consider in risk communication. Building trust is tremendously effective when done through social media and collaboration with organizations trusted by the communities (Vergara et al., 2021; Wild et al., 2021). The community-based approach holds significant value, especially to African American communities, which the American healthcare system has historically discriminated against and mistreated. Efforts should center around why testing, masking, vaccinating, etc., are scientifically effective in mitigating the disease outbreak and how people can best protect themselves from infections. Doing so will be critical to establishing a broad acceptance and compliance with these interventions.

Addressing Challenges with Implementation

During the COVID-19 pandemic, the United States dealt with resource challenges and delays in the initial response that impeded the country's ability to mitigate the consequences of the pandemic. In the instance of PPE, particularly N95 masks, the U.S. relies heavily on exporters (Jacobs, 2020). However, when the global supply chain was no longer available, as foresaw by experts during the COVID-19 pandemic, the only national repository of emergency medical equipment and supplies, called the SNS, had only around 1% of the masks needed by the country (Elgin & Tozzi, 2020). This unpreparedness was due to years of budget-cutting and neglect that rendered the department incapable of supplying hospitals during a large outbreak (Finkenstadt et al., 2020). Hence, in addition to strengthening international collaboration, a strategy plan between U.S.-based companies and the government for emergency production of medical equipment and other needed supplies and an updated repository are needed to ensure the country's ability to combat future outbreaks. In addition, different governance systems impact the implementation of restrictive or controversial public health interventions. With a small democratic government structure and limited leverage on the healthcare system, the U.S. heavily relies on the general public's willingness to adhere to public health measures, further emphasizing the need for transparency and active communication on part of the government and health officials.

The Environment & Identifying Future Threats

Lastly, the rapid emergence of pathogens that have led to the global spread of contagious illnesses will continue with ever-increasing speed as more places become ideal for viruses. Deforestation, which makes the encounters between humans and wildlife more frequent, increases the likelihood of a zoonotic jump that can lead to the emergence of new pathogens and pandemic-level outbreaks (Dobson et al., 2020). Therefore, policies influencing the protection of natural environments, funding for continuous observation, and research in susceptible regions are top international public health priorities in the long-term prevention of new pandemics.

Conclusion

Though the U.S. and the rest of the world were caught off-guard by the COVID-19 pandemic, significant strides in mitigating outbreaks and the consequences of COVID-19 are made despite the initial setback. Through this literature review, I have found many of the public health interventions adopted during COVID-19 have demonstrated notable effectiveness. The varying degree of success in using these measures was connected to the timing and ways in which different countries implemented them, thus, highlighting the importance of effective implementation. With the world resuming pre-pandemic activities, it is understandable that many may want to leave behind the three years of restrictions and constant interruptions to our lives. However, as new disease outbreaks and pandemics are inevitable, a phrase with increasing relevance as Monkeypox becomes prevalent, I believe vigilance in watching for new pathogens and reflection should characterize our new normalcy. Careful examination of our management of the COVID-19 pandemic and subsequent revisions in pandemic strategies will lead to better preparedness for future pandemics and prevent the level of harm observed in this pandemic from reoccurring.

References

Abdelrahman, Z., Li, M., & Wang, X. (2020). Comparative review of SARS-COV-2, SARS-COV, MERS-COV, and influenza A respiratory viruses. *Frontiers in Immunology*, *11*. https://doi.org/10.3389/fimmu.2020.552909

Adams-Prassl, A., Boneva, T., Golin, M., & Rauh, C. (2020). The impact of the coronavirus lockdown on mental health: evidence from the US. https://doi.org/10.17863/CAM.81910

An, B. Y., Porcher, S., Tang, S. Y., & Kim, E. E. (2021). Policy design for covid -19: Worldwide evidence on the efficacies of early mask mandates and other policy interventions. *Public Administration Review*, *81*(6), 1157–1182. https://doi.org/10.1111/puar.13426

Bouffanais, R., & Lim, S. S. (2020, July 10). *Cities - try to predict superspreading hotspots for COVID-19*. Nature News. Retrieved July 27, 2022, from https://www.nature.com/articles/d41586-020-02072-3?fbclid=IwAR3kEU6A-WgeyxBAQRHrlfg0xvDEB7f7CdBKIjFThTm87UQuyiyB_au1fYY

Centers for Disease Control and Prevention. (2018) Understanding The Differences [Inforgraphic]. Centers for Disease Control and Prevention. https://www.cdc.gov/niosh/npptl/pdfs/understanddifferenceinfographic-508.pdf

Centers for Disease Control and Prevention. (2022a). *Overview of covid-19 vaccines*. Centers for Disease Control and Prevention. Retrieved August 6, 2022, from https://www.cdc.gov/coronavirus/2019-ncov/vaccines/different-vaccines/overview-COVID-19-vaccines.html

Centers for Disease Control and Prevention. (2022b). *Covid-19 testing: What you need to know*. Centers for Disease Control and Prevention. Retrieved July 27, 2022, from https://www.cdc.gov/coronavirus/2019-ncov/symptoms-testing/testing.html#:~:text=Viral%20tests%20look%20for%20a,be%20recommended%20over%20the%20other.

Cha, S. (2022, March 17). *How South Korea is beating Covid despite 600,000 new cases a day*. Bloomberg.com. Retrieved July 27, 2022, from https://www.bloomberg.com/news/articles/2022-03-17/how-south-korea-is-beating-covid-despite-600-000-new-cases-a-day

Chang, S., Pierson, E., Koh, P. W., Gerardin, J., Redbird, B., Grusky, D., & Leskovec, J. (2020). Mobility network models of COVID-19 explain inequities and inform reopening. *Nature*, *589*(7840), 82–87. https://doi.org/10.1038/s41586-020-2923-3

Chen, P. Z., Koopmans, M., Fisman, D. N., & Gu, F. X. (2021). Understanding why superspreading drives the COVID-19 pandemic but not the H1N1 pandemic. *The Lancet Infectious Diseases*, *21*(9), 1203–1204. https://doi.org/10.1016/s1473-3099(21)00406-0

Cheng, Y., Ma, N., Witt, C., Rapp, S., Wild, P. S., Andreae, M. O., Pöschl, U., & Su, H. (2021). Face masks effectively limit the probability of SARS-COV-2 transmission. *Science*, *372*(6549), 1439–1443. https://doi.org/10.1126/science.abg6296

Chernozhukov, V., Kasahara, H., & Schrimpf, P. (2021). Causal impact of masks, policies, behavior on early covid-19 pandemic in the U.S. *Journal of Econometrics*, *220*(1), 23–62. https://doi.org/10.1016/j.jeconom.2020.09.003

Choi, Y., Kim, J. S., Kim, J. E., Choi, H., & Lee, C. H. (2021). Vaccination prioritization strategies for covid-19 in Korea: A mathematical modeling approach. *International Journal of Environmental Research and Public Health*, *18*(8), 4240. https://doi.org/10.3390/ijerph18084240

Clark, E., Chiao, E. Y., & Amirian, E. S. (2020). Why contact tracing efforts have failed to curb coronavirus disease 2019 (COVID-19) transmission in much of the United States. *Clinical Infectious Diseases*, *72*(9). https://doi.org/10.1093/cid/ciaa1155

Dobson, A. P., Pimm, S. L., Hannah, L., Kaufman, L., Ahumada, J. A., Ando, A. W., Bernstein, A., Busch, J., Daszak, P., Engelmann, J., Kinnaird, M. F., Li, B. V., Loch-Temzelides, T., Lovejoy, T., Nowak, K., Roehrdanz, P. R., & Vale, M. M. (2020). Ecology and economics for pandemic prevention. *Science*, *369*(6502), 379–381. https://doi.org/10.1126/science.abc3189

Dunford, D., de la Torre Arenas, I., Ahmed, M., Lowther, E., Stylianou, N., & Dale, B. (2020, April 6). *Coronavirus: The World in Lockdown in maps and charts*. BBC News. Retrieved July 10, 2022, from https://www.bbc.com/news/world-52103747

Elgin, B., & Tozzi, J. (2020, March 18). *Hospital makes face masks, covid-19 shields from office supplies*. Bloomberg.com. Retrieved August 13, 2022, from https://www.bloomberg.com/news/articles/2020-03-18/hospital-makes-face-masks-covid-19-shields-from-office-supplies

Endo, A., Leclerc, Q. J., Knight, G. M., Medley, G. F., Atkins, K. E., Funk, S., & Kucharski, A. J. (2021). Implication of backward contact tracing in the presence of overdispersed transmission in COVID-19 outbreaks. *Wellcome Open Research*, *5*, 239. https://doi.org/10.12688/wellcomeopenres.16344.3

Fetzer, T., & Graeber, T. (2021). Measuring the scientific effectiveness of contact tracing: Evidence from a natural experiment. *Proceedings of the National Academy of Sciences*, *118*(33). https://doi.org/10.1073/pnas.2100814118

Finkenstadt, D., Handfield, R., & Guinto, P. (2021, February 1). *Why the U.S. still has a severe shortage of medical supplies*. Harvard Business Review. Retrieved August 11, 2022, from https://hbr.org/2020/09/why-the-u-s-still-has-a-severe-shortage-of-medical-supplies

Fleisher, O., Gianordoli, G., Parshina-kottas, Y., Patanjali, K., Peyton, M., & Saget, B. (2020, October 30). *Masks work. really. we'll show you how*. The New York Times. Retrieved July 25, 2022, from https://www.nytimes.com/interactive/2020/10/30/science/wear-mask-covid-particles-ul.html

Funk, C., Tyson, A., Pasquini, G., & Spencer, A. (2022, July 7). *Americans reflect on nation's COVID-19 response*. Pew Research Center Science & Society. Retrieved August 30, 2022, from https://www.pewresearch.org/science/2022/07/07/americans-reflect-on-nations-covid-19-response/

Glogowsky, U., Hansen, E., & Schächtele, S. (2021). How effective are social distancing policies? evidence on the fight against COVID-19. *PLOS ONE*, *16*(9). https://doi.org/10.1371/journal.pone.0257363

Goldstein, J. R., Cassidy, T., & Wachter, K. W. (2021). Vaccinating the oldest against covid-19 saves both the most lives and most years of life. *Proceedings of the National Academy of Sciences*, *118*(11). https://doi.org/10.1073/pnas.2026322118

Hale, T., Angrist, N., Goldszmidt, R., Kira, B., Petherick, A., Phillips, T., Webster, S., Cameron-Blake, E., Hallas, L., Majumdar, S., & Tatlow, H. (2021). A global panel database of pandemic policies (Oxford Covid-19 Government response tracker). *Nature Human Behaviour*, *5*(4), 529–538. https://doi.org/10.1038/s41562-021-01079-8

Howard, J., Huang, A., Li, Z., Tufekci, Z., Zdimal, V., van der Westhuizen, H.-M., von Delft, A., Price, A., Fridman, L., Tang, L.-H., Tang, V., Watson, G. L., Bax, C. E., Shaikh, R., Questier, F., Hernandez, D., Chu, L. F., Ramirez, C. M., & Rimoin, A. W. (2021). An evidence review of face masks against covid-19. *Proceedings of the National Academy of Sciences*, *118*(4). https://doi.org/10.1073/pnas.2014564118

Huang, Y., Yang, C., Xu, X.-feng, Xu, W., & Liu, S.-wen. (2020). Structural and functional properties of SARS-COV-2 spike protein: Potential antivirus drug development for covid-19. *Acta Pharmacologica Sinica*, *41*(9), 1141–1149. https://doi.org/10.1038/s41401-020-0485-4

Inoue, H., Murase, Y., & Todo, Y. (2021). Do economic effects of the anti-covid-19 lockdowns in different regions interact through supply chains? *PLOS ONE*, *16*(7). https://doi.org/10.1371/journal.pone.0255031

Ives, M. (2022, January 15). *Americans are just learning what people in East Asia already know about masks*. The New York Times. Retrieved August 30, 2022, from https://www.nytimes.com/2022/01/15/world/china-masks-usa.html

Jacobs, A. (2020, July 8). *Grave shortages of protective gear flare again as Covid Cases Surge*. The New York Times. Retrieved August 25, 2022, from https://www.nytimes.com/2020/07/08/health/coronavirus-masks-ppe-doc.html

Johns Hopkins Coronavirus Resource Center. (2022). *Mortality analyses*. Johns Hopskins Coronavirus Resource Center. Retrieved July 28, 2022, from https://coronavirus.jhu.edu/data/mortality

Juneau, C.-E., Pueyo, T., Bell, M., Gee, G., Collazzo, P., & Potvin, L. (2022). Lessons from past pandemics: A systematic review of evidence-based, cost-effective interventions to suppress COVID-19. *Systematic Reviews*, *11*(1). https://doi.org/10.1186/s13643-022-01958-9

Kang, S.-J., Kim, S., Park, K.-H., Jung, S. I., Shin, M.-H., Kweon, S.-S., Park, H., Choi, S.-W., Lee, E., & Ryu, S. Y. (2021). Successful control of covid-19 outbreak through tracing, testing, and isolation: Lessons learned from the outbreak control efforts made in a Metropolitan City of South Korea. *Journal of Infection and Public Health*, *14*(9), 1151–1154. https://doi.org/10.1016/j.jiph.2021.07.003

Kojaku, S., Hébert-Dufresne, L., Mones, E., Lehmann, S., & Ahn, Y.-Y. (2021). The effectiveness of backward contact tracing in networks. *Nature Physics*, *17*(5), 652–658. https://doi.org/10.1038/s41567-021-01187-2

Krisberg, K. (2020, August 1). *Essential workers facing higher risks during COVID-19 outbreak: Meat Packers, retail workers sickened*. The Nation's Health. Retrieved August 30, 2022, from https://www.thenationshealth.org/content/50/6/1.1

Leffler, C. T., Ing, E., Lykins, J. D., Hogan, M. C., McKeown, C. A., & Grzybowski, A. (2020). Association of country-wide coronavirus mortality with demographics, testing, lockdowns, and public wearing of masks. *The American Journal of Tropical Medicine and Hygiene*, *103*(6), 2400–2411. https://doi.org/10.4269/ajtmh.20-1015

Liang, M., Gao, L., Cheng, C., Zhou, Q., Uy, J. P., Heiner, K., & Sun, C. (2020). Efficacy of face mask in preventing respiratory virus transmission: A systematic review and meta-analysis. *Travel Medicine and Infectious Disease*, *36*, 101751. https://doi.org/10.1016/j.tmaid.2020.101751

Majra, D., Benson, J., Pitts, J., & Stebbing, J. (2021). SARS-COV-2 (COVID-19) superspreader events. *Journal of Infection*, *82*(1), 36–40. https://doi.org/10.1016/j.jinf.2020.11.021

McClain, C., & Rainie, L. (2021, May 25). *The challenges of contact tracing as U.S. battles covid-19*. Pew Research Center: Internet, Science & Tech. Retrieved August 30, 2022, from https://www.pewresearch.org/internet/2020/10/30/the-challenges-of-contact-tracing-as-u-s-battles-covid-19/

Miller, S. L., Nazaroff, W. W., Jimenez, J. L., Boerstra, A., Buonanno, G., Dancer, S. J., Kurnitski, J., Marr, L. C., Morawska, L., & Noakes, C. (2020). Transmission of SARS-COV-2 by inhalation of respiratory aerosol in the Skagit Valley Chorale Superspreading Event. *Indoor Air*, *31*(2), 314–323. https://doi.org/10.1111/ina.12751

Mitze, T., Kosfeld, R., Rode, J., & Wälde, K. (2020). Face masks considerably reduce COVID-19 cases in Germany. *Proceedings of the National Academy of Sciences*, *117*(51), 32293–32301. https://doi.org/10.1073/pnas.2015954117

Nguyen, L. H., Drew, D. A., Graham, M. S., Joshi, A. D., Guo, C.-G., Ma, W., Mehta, R. S., Warner, E. T., Sikavi, D. R., Lo, C.-H., Kwon, S., Song, M., Mucci, L. A., Stampfer, M. J., Willett, W. C., Eliassen, A. H., Hart, J. E., Chavarro, J. E., Rich-Edwards, J. W., … Zhang, F. (2020). Risk of COVID-19 among front-line health-care workers and the general community: A prospective cohort study. *The Lancet Public Health*, *5*(9). https://doi.org/10.1016/s2468-2667(20)30164-x

Ontario Agency for Health Protection and Promotion (Public Health Ontario). Focus on: backward contact tracing. Toronto, ON: Queen's Printer for Ontario; 2021.

Rawson, T., Brewer, T., Veltcheva, D., Huntingford, C., & Bonsall, M. B. (2020). How and when to end the COVID-19 lockdown: An optimization approach. *Frontiers in Public Health*, *8*. https://doi.org/10.3389/fpubh.2020.00262

Rich, M., & Hayashi, N. (2020, June 6). *Is the secret to Japan's virus success right in front of its face?* The New York Times. Retrieved August 11, 2022, from https://www.nytimes.com/2020/06/06/world/asia/japan-coronavirus-masks.html Ritchie, H., Rodes-Guirao, L., Appel, C., Giattino, C., Ortiz-Ospina, E., Hasell, J., Macdonald, B., Beltekian, D., & Roser, M. (2020). "Coronavirus Pandemic (COVID-19)". Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/coronavirus' [Online Resource]

Robinson, P. C., Liew, D. F., Tanner, H. L., Grainger, J. R., Dwek, R. A., Reisler, R. B., Steinman, L., Feldmann, M., Ho, L.-P., Hussell, T., Moss, P., Richards, D., & Zitzmann, N. (2022). Covid-19 therapeutics: Challenges and directions for the future. *Proceedings of the National Academy of Sciences*, *119*(15). https://doi.org/10.1073/pnas.2119893119

Samavati, L., & Uhal, B. D. (2020). ACE2, much more than just a receptor for SARS-COV-2. *Frontiers in Cellular and Infection Microbiology*, *10*. https://doi.org/10.3389/fcimb.2020.00317

Schive, K. (2021, November 6). *How does the COVID-19 antigen test work?* MIT Medical. Retrieved August 30, 2022, from https://medical.mit.edu/covid-19-updates/2020/05/how-does-covid-19-antigen-test-work#:~:text=While%20other%20diagnostic%20tests%20for,or%20days%20to%20get%20results.

Selden, T. M., & Berdahl, T. A. (2021). Risk of severe COVID-19 among workers and their household members. *JAMA Internal Medicine*, *181*(1), 120. https://doi.org/10.1001/jamainternmed.2020.6249

Shear, M. D., Goodnough, A., Kaplan, S., Fink, S., Thomas , K., & Weiland, N. (2020, March 28). *The Lost Month: How a failure to test blinded the U.S. to covid-19*. The New York Times. Retrieved August 2, 2022, from https://www.nytimes.com/2020/03/28/us/testing-coronavirus-pandemic.html

Strochlic, N., & Champine, R. D. (2020, March 27). *How some cities 'flattened the curve' during the 1918 flu pandemic*. Retrieved July 26, 2022, from https://www.nationalgeographic.com/history/article/how-cities-flattened-curve-1918-spanish-flu-pandemic-coronavirus/

Sun, C., & Zhai, Z. (2020). The efficacy of social distance and ventilation effectiveness in preventing COVID-19 transmission. *Sustainable Cities and Society*, *62*, 102390. https://doi.org/10.1016/j.scs.2020.102390

Suñer, C., Coma, E., Ouchi, D., Hermosilla, E., Baro, B., Rodríguez-Arias, M. À., Puig, J., Clotet, B., Medina, M., & Mitjà, O. (2022). Association between two mass-gathering outdoor events and incidence of SARS-COV-2 infections during the fifth wave of covid-19 in north-east Spain: A population-based control-matched analysis. *The Lancet Regional Health - Europe*, *15*, 100337. https://doi.org/10.1016/j.lanepe.2022.100337

Vergara, R. J. D., Sarmiento, P. J. D., & Lagman, J. D. N. (2021, January 18). *Building Public Trust: A response to COVID-19 vaccine hesitancy predicament*. OUP Academic. Retrieved August 30, 2022, from https://doi.org/10.1093/pubmed/fdaa282

Wamsley, L. (2020, December 7). *Think health care workers are tested often for the coronavirus? think again.* NPR. Retrieved August 2, 2022, from https://www.npr.org/2020/12/07/943945361/think-health-care-workers-are-tested-often-for-covid-19-think-again

Wild, A., Kunstler, B., Goodwin, D., Onyala, S., Zhang, L., Kufi, M., Salim, W., Musse, F., Mohideen, M., Asthana, M., Al-Khafaji, M., Geronimo, M. A., Coase, D., Chew, E., Micallef, E., & Skouteris, H. (2021). Communicating covid-19 health information to culturally and linguistically diverse communities: Insights from a participatory research collaboration. *Public Health Research & Practice*, *31*(1). https://doi.org/10.17061/phrp3112105

World Health Organization. (2020a, July 9). *Transmission of SARS-COV-2: Implications for infection prevention precautions*. World Health Organization. Retrieved June 15, 2022, from https://www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-infection-prevention-precautions

World Health Organization. (2020b). *Advice on the use of masks in the context of COVID-19: interim guidance, 6 April 2020* (No. WHO/2019-nCov/IPC_Masks/2020.3). World Health Organization.

World Health Organization. (2021a, January 12). *The different types of covid-19 vaccines*. World Health Organization. Retrieved July 23, 2022, from https://www.who.int/news-room/feature-stories/detail/the-race-for-a-covid-19-vaccine-explained

World Health Organization. (2021b). *Coronavirus disease (covid-19): How is it transmitted?* World Health Organization. Retrieved July 26, 2022, from https://www.who.int/news-room/questions-and-answers/item/coronavirus-disease-covid-19-how-is-it-transmitted

World Health Organization. (2022a, March 15). *Coronavirus disease (covid-19): Pregnancy, childbirth and the postnatal period*. World Health Organization. Retrieved August 1, 2022, from https://www.who.int/news-room/questions-and-answers/item/coronavirus-disease-covid-19-pregnancy-and-childbirth

World Health Organization. (2022b, July 6). *Contact tracing and quarantine in the context of covid-19: Interim guidance, 6 July 2022*. World Health Organization. Retrieved August 3, 2022, from https://www.who.int/publications/i/item/WHO-2019-nCoV-Contact_tracing_and_quarantine-2022.1

World Health Organization. (2022c). *Severe acute respiratory syndrome (SARS)*. World Health Organization. Retrieved July 24, 2022, from https://www.who.int/health-topics/severe-acute-respiratory-syndrome#tab=tab_1

Worobey, M., Levy, J. I., Malpica Serrano, L., Crits-Christoph, A., Pekar, J. E., Goldstein, S. A., Rasmussen, A. L., Kraemer, M. U., Newman, C., Koopmans, M. P., Suchard, M. A., Wertheim, J. O., Lemey, P., Robertson, D. L., Garry, R. F., Holmes, E. C., Rambaut, A., & Andersen, K. G. (2022). The Huanan Seafood Wholesale Market in Wuhan was the early epicenter of the COVID-19 pandemic. *Science*, *377*(6609), 951–959. https://doi.org/10.1126/science.abp8715

Yechezkel, M., Weiss, A., Rejwan, I., Shahmoon, E., Ben-Gal, S., & Yamin, D. (2021). Human mobility and poverty as key drivers of covid-19 transmission and control. *BMC Public Health*, *21*(1). https://doi.org/10.1186/s12889-021-10561-x

Yekta, R., Vahid-Dastjerdi, L., Norouzbeigi, S., & Mortazavian, A. M. (2021). Food products as potential carriers of SARS-COV-2. *Food Control*, *123*, 107754. https://doi.org/10.1016/j.foodcont.2020.107754

Zhang, Y. S., Noels, K. A., Young-Leslie, H., & Lou, N. M. (2022). “responsible” or “strange?” differences in face mask attitudes and use between Chinese and Non-East asian Canadians during COVID-19’s first wave. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.853830