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Human behaviors during the COVID-19 pandemic and their consequences

Robert Martin*

Bell Labs, New Jersey, United States of America

Abstract

COVID-19 accounted for about 1.1 million deaths in the United States, 365,000 in 2020 alone, and about 7 million worldwide. Due to underreporting, the actual global COVID-19-related deaths were likely between 15 and 30 million, with around 4 million in 2020. As devastating as these numbers were, without any behavioral changes—whether voluntary or mandated—deaths in the United States would have been about 8 million, and global deaths about 115 million, all within 2020. Behavioral measures included border closure, air filtration, surface disinfection, handwashing, wearing glasses/goggles, testing, contact tracing, and politically mandated nonpharmaceutical interventions such as mask-wearing, social distancing, school closures, and lockdowns. These measures significantly reduced mortality rates. Depending on the specific behaviors adopted and the extent of vaccination coverage, countries worldwide experienced widely varying outcomes—ranging from essentially no increase in deaths to overwhelming surges. Each country's COVID-19 response was shaped by its leadership, making political decision-making a decisive factor in pandemic outcomes. Furthermore, recommended behaviors became heavily politicized and were implemented and adhered to unevenly. Each mandated behavior had significant negative consequences, such as reduced learning, diminished socialization, and increased incidences of measles and polio. In addition, maintaining safety required sacrificing quality of life. The most impactful measure was isolation, which contributed to increased stress, mental health problems, and delays in medical treatment—factors that led to higher mortality rates and deaths of despair. Moreover, a range of unusual human behaviors emerged. Misinformation spread rapidly, resulting in lower vaccination rates and reduced adherence to safe practices. Interestingly, even animal behaviors changed. Hence, this paper discusses behaviors during the COVID-19 pandemic and their far-reaching consequences.

Keywords: COVID-19; Nonpharmaceutical interventions; Lockdowns; Social distancing; School closures

***Corresponding author:**
Robert Martin
(bobmartin08008@mac.com)

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1. Introduction

Human behavior, to put it mildly, is complex, unpredictable, and frustratingly irrational. Our COVID-related behaviors disrupted fragile equilibria and impacted our health, socialization, education, and economy. Since the beginning of the pandemic, a comprehensive document titled *The Mouse that Roared* has been compiled to summarize COVID research. The title reflects the fact that, in historical context, severe acute

respiratory syndrome coronavirus 2 (SARS-CoV-2) is a relatively mild virus that has caused huge societal impacts. The 23,000-page document contains approximately 22,000 paper summaries drawn from 2,250 sources. Most of these papers originate from journals and platforms such as *Nature*, *Cell*, *Science*, *Frontiers*, MDPI, Sage, *Cureus*, *JAMA*, the American Health Association, *The British Medical Journal*, *New England Journal of Medicine*, *PLOS*, *BMC*, Wiley, *Proceedings of the National Academy of Sciences*, bioRxiv, medRxiv, preprints.org, SSRN, Research Square, and the Centers for Disease Control and Prevention (CDC). The six chapters—"How People Behaved," "Avoiding COVID," "Politics and National COVID Responses," "Herd Immunity," "Superspreaders and Superspreading Events," and "Pandemic Medical Impacts"—along with the 4,500 paper summaries, form the foundation of this review.

2. The significance of behavior during a pandemic

Let us consider a Gedanken thought experiment to see what would have happened if no one had changed their behavior during the pandemic. An April 2021 CDC *Mortality and Morbidity Weekly Report* paper presented data on COVID-19 in the United States (US) in 2020, as shown in Figure 1.

This 4.9% rate is consistent with Our World of Data's world case fatality rates, which were 5.2% for the same interval. Case fatality rates are calculated as confirmed deaths divided by confirmed cases. Confirmed cases typically represent symptomatic cases, which accounted for only 60% of the cases. In addition, many mild cases would have been interpreted as the flu or a mild cold. Thus, it is reasonable to assume that the actual number of cases was twice as high, resulting in an estimated case fatality rate of 2.5% for all infections. Assuming no changes in behavior and applying these death rates, Table 1 shows the projected number of deaths by age in the US, corresponding to an overall 2.5% death rate.

The global COVID-19 death rate would have been lower than that of the US due to its lower overall age rate. Globally, if there had been no behavioral changes, there would have been about 115 million deaths or a 1.5% case fatality rate.

With the Wuhan variant of COVID-19, which had a viral reproduction number (R_0) of 2.5, cases would have grown exponentially—as observed in the first few weeks in the US outbreak (later in the pandemic, SARS-CoV-2's R_0 reached double digits). Under this scenario, everyone in the US would have been infected by mid-summer, rendering vaccines ineffective, and hospitals would have been extremely overloaded. This scenario epitomizes the remark by Boris Johnson, then Prime Minister of the United Kingdom, that "COVID is just nature's way of dealing with old people."

The October 2020 Great Barrington Declaration, which was endorsed by the US President at the time, Donald Trump, suggested that elderly individuals stay home, while allowing others to become infected, thereby achieving herd immunity and avoiding school closures. Assuming this approach had been implemented early in the pandemic, herd immunity might have been attainable if people aged 50 and older stayed home; however, the number of deaths would be equal to the actual pandemic toll. If the threshold had been raised to isolate the 60+ age group instead, deaths would have doubled. To complicate matters further, new variants would have required subsequent Great Barrington Declarations.

2.1. Differences between countries

COVID-19 deaths and excess deaths dramatically reflected the impacts of different countries' pandemic behavioral responses. Had the US matched the average performance

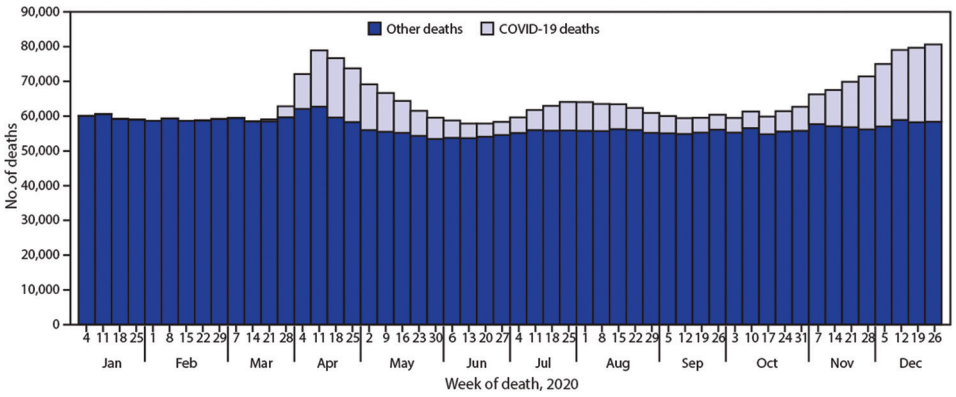

Figure 1. United States COVID deaths. Image obtained from Ahmad *et al.*, 2021.

Table 1. Projected deaths in the United States, if there were no behavioral changes

Age	Men	Women	Total
<29	96,964	97,459	194,422
30–39	56,067	54,418	110,486
40–49	110,651	112,465	223,116
50–59	306,722	321,563	628,286
60–69	877,291	955,621	1,832,912
70–79	1,353,535	1,579,124	2,932,659
>80	1,220,292	1,171,481	2,391,773
Total	4,021,522	4,292,131	8,313,653

of countries such as Japan, South Korea, Taiwan, Singapore, Australia, and New Zealand, there would have been 700,000 fewer deaths in the US. In other words, roughly seven out of the 10 COVID-related deaths in the US would have been prevented through rational behavior. This raises the critical question: Why did the US have such terrible outcomes?

3. The role of the leader

All countries' pandemic responses were shaped by their respective leaders. No country delegated that responsibility to its public health agencies. A country's leader established practices and acted as a role model, thus influencing public behavior and determining COVID-19 outcomes.

The significance of leadership was starkly demonstrated by the 1991 Milgram experiment at Yale (Blass, 1991). The experiment demonstrated the overwhelming power of authority and provided the psychological evidence that people will blindly and obediently follow leaders. Remarkably, two-thirds of the participants in the experiment administered a potentially lethal shock to another participant after s/he was allegedly unconscious simply because someone in a White coat told them to do so.

Adding to people's inbred, lemming-like behaviors, the threat, uncertainty, and urgency associated with a crisis like the pandemic magnify a leader's power. This dynamic helps explain why 4% of adult respondents said they drank or gargled diluted bleach after Trump's ill-advised suggestion to drink bleach.

4. People's behavior

4.1. COVID-19 infection

SARS-CoV-2 infects the host by entering the body through the mouth, nose, or eyes. The virus cannot enter the body through the skin, open sores, or ingestion of contaminated food. Thus, transmission primarily occurs through airborne exposure and contact with the mucous membranes of the face.

Although not officially recognized by the World Health Organization until December 2022, SARS-CoV-2 spreads mainly through small droplets in aerosol, rather than large droplets. Infection typically requires exposure to about 100 viral particles. However, transmission could occur with as few as three viral particles. Compounding this risk, Bleicker *et al.* (2021) found that infected individuals can release up to hundreds of millions of viral particles.

Airborne transmission occurs through several means:

(i) Breathing releases 50–5,000 droplets. Most of these droplets are low velocity and fall to the ground quickly. Fewer droplets are released through breathing through the nose.

(ii) Sneezing produces approximately 30,000 droplets, with droplets traveling at speeds up to 200 miles per hour. Infected individuals may release up to 200 million viral particles in a single cough or sneeze.

(iii) A toilet flush generates about 8,000 droplets if the seat is left open. Infections have resulted from toilet flushes.

SARS-CoV-2 viral particles can also be transmitted through surfaces. A study by Chatterjee *et al.* (2021) reported the persistence of the SARS-CoV-2 virus particles on hard surfaces, as shown in Table 2.

With the emergence of variants, SARS-CoV-2's infectiousness grew. The original Wuhan strain had an R_0 of 2.5, followed by Alpha at 3.0, Delta at 5.0, and the original Omicron variant at 8.2. Since then, the transmissibility has continued to rise.

5. Common settings for SARS-CoV-2 transmission

Having established how infection happens, the next question is where. According to Grabowski *et al.* (2020), the primary settings for SARS-CoV-2 spread include households, within the community, which is fueled by superspreaders, and interregional transmission networks.

A meta-analysis by Dean *et al.* (2020), which reviewed 54 relevant studies with 77,758 participants regarding household secondary transmission, reported that the estimated household secondary attack rate was 16.6% (95% confidence interval [CI]: 14.0–19.3%), which was higher than the secondary attack rates for SARS-CoV-1 (7.5%; 95% CI: 4.8–10.7%) and Middle East respiratory syndrome (MERS) coronavirus (4.7%; 95% CI: 0.9–10.7%). Household secondary attack rates from symptomatic index cases (18.0%; 95% CI, 14.2–22.1%) were higher than from asymptomatic index cases (0.7%; 95% CI: 0–4.9%). Adult

Table 2. Virus survival time

Material	Average survival time
Plastic	Up to 7 days
Stainless steel	Up to 7 days
Metal	Up to 5 days
Glass	Up to 4 days
Ceramic	Up to 4 days
Paper money	Up to 2 days
Unvarnished wood	Up to 1 day
Cloth	Up to 1 day
Cardboard	Up to 1 day
Paper	Up to 30 min
Tissue paper	Up to 30 min

contacts (28.3%; 95% CI: 20.2–37.1%) had more infections than child contacts (16.8%; 95% CI: 12.3–21.7%), with spouses (37.8%; 95% CI: 25.8–50.5%) experiencing more infections than other family contacts (17.8%; 95% CI: 11.7–24.8%).

5.1. Community spread

Three major factors are implicated in community spread: the activities of other people, the location, and the presence of a nearby superspreader.

Alsved *et al.* (2020) reported that there are huge ranges in viral spread depending on a person's activity, as shown in Figure 2. Notably, the impact of wearing a face mask is shown by the rightmost bar in Figure 2.

Alsved *et al.*, (2020) reported that the type of wind instrument used in orchestras significantly affects viral spread. Instruments that are larger and oriented more directly toward the audience—rather than toward the ceiling or floor—tend to disperse greater quantities of viral particles.

Location also plays a crucial role, as venues vary in crowd density and ventilation quality. Viral infection rates associated with the reopening of various US venues and activities.

Another primary factor influencing COVID-19 spread is the presence of superspreaders and superspreading events. Not all people emit the same number of viral particles; rather, the distribution follows a negative binomial distribution, where a small percentage of people account for the majority of viral emissions. Yang *et al.* (2021) reported that just 2% of individuals carry 90% of the population's viral load, as shown in Figure 3.

Meagher and Friel (2022) estimated that 20% of index cases, those with the high viral load, accounted

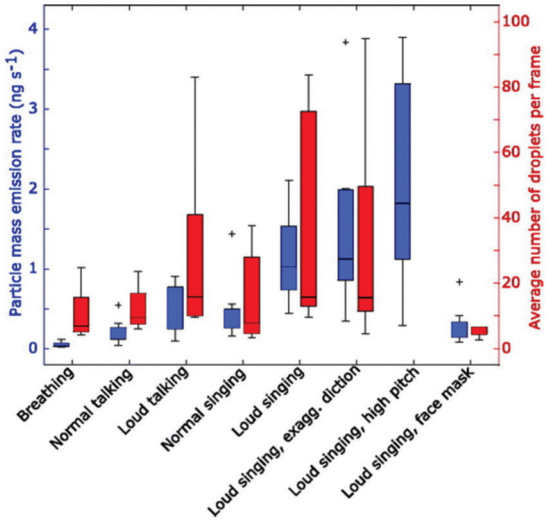

Figure 2. Severe acute respiratory syndrome coronavirus 2 aerosol spray rates. Image obtained from Alsved *et al.*, 2020.

for approximately 75–98% of the expected secondary infections. The index case or patient zero is the first documented patient in a disease epidemic within a population, or the first documented patient included in an epidemiological study. A superspreader event happens when an event is crowded and/or is indoors and exhibits uninhibited social behavior. Superspreading occurred in restaurants, bars, nightclubs, churches, nursing homes, prisons, cruise ships, airplanes (particularly boarding), homeless shelters, colleges, sporting events, and the Sturgis motorcycle rally.

In May 2020, the CDC erroneously recommended maintaining a six-foot distance as a sufficient preventive measure; however, infections happened in unexpected ways. Wong *et al.* (2022) documented a case in which a vaccinated individual contracted COVID-19 from another vaccinated, infected person staying in a hotel room across the hallway, likely due to viral particles travelling under the doors.

6. Prevention of COVID-19 infection

As discussions on non-pharmaceutical interventions (NPIs) unfold, it will become clear that it was possible to avoid SARS-CoV-2 infection. However, beyond ignorance, a major reason that so many people got infected was the challenging tradeoff between safety and quality of life. Not being able to go to restaurants, movies, and sporting events greatly impacted many people's enjoyment of life. Face masks were uncomfortable, and taking a rapid antigen test before seeing friends was onerous. Consequently, many chose quality of life over safety. For younger people, particularly later in the pandemic, this was a rational choice.

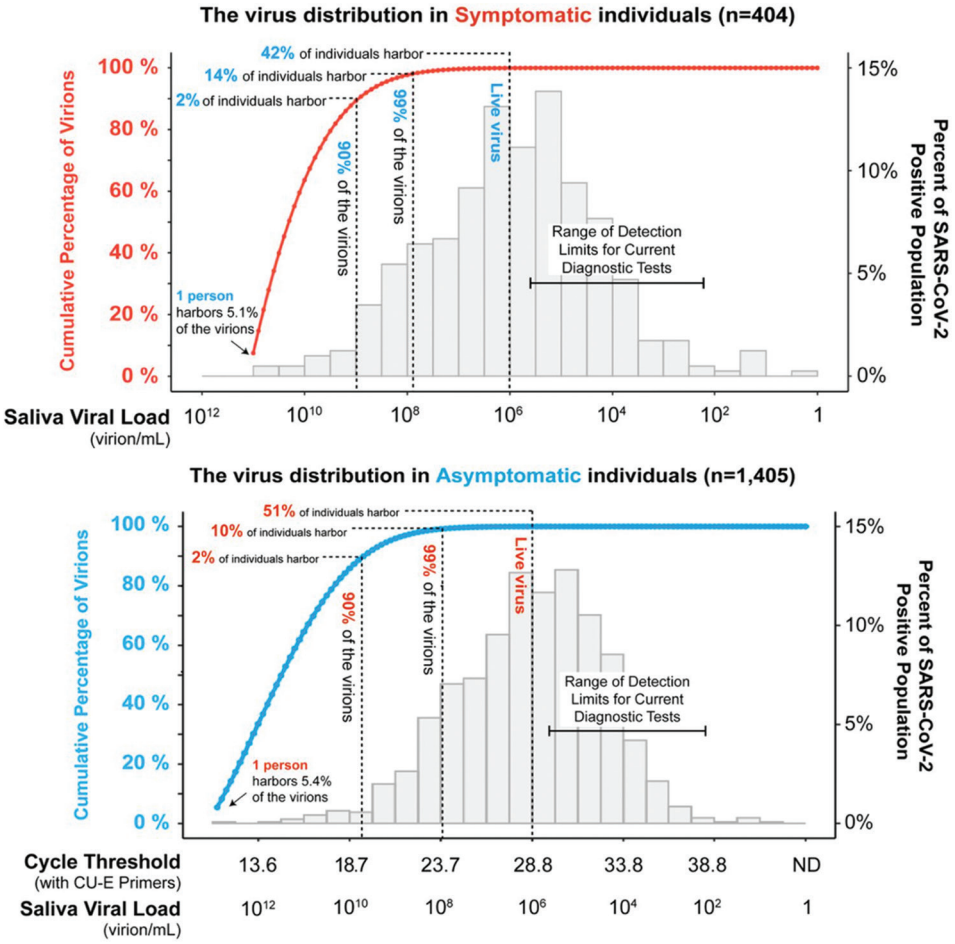

Figure 3. Percentage of viral load in symptomatic and asymptomatic individuals. Image obtained from Yang *et al.*, 2021.

6.1. Pharmaceutical interventions

Even though SARS-CoV-2 is highly infectious, the infection can be prevented primarily through vaccinations and/or therapeutics. When the initial messenger RNA vaccine trial results were published in December 2020, the prospect of achieving herd immunity and ending the pandemic seemed within reach. Moderna's vaccine showed 94.1% efficiency (95% CI: 89.3–96.8%) (Baden *et al.*, 2020) and Pfizer's demonstrated 94.8% efficacy (95% CI: 89.8–97.6%) (Polack *et al.*, 2020) against the infection. These spectacular results took many by surprise.

The proportion of the population that must be immune from infection to achieve herd immunity is greatly influenced by R_0, which reflects how many people an average person will infect in a new environment. With ~95% vaccine effectiveness against infection and the Wuhan strains' R_0 of 2.5, roughly 65% of the population needed to be vaccinated or previously infected to achieve herd immunity. However, with Delta's higher R_0 of 5 and the low vaccination rates in the US, achieving herd immunity through vaccination alone became unattainable.

Furthermore, as the variants evolved, SARS-CoV-2 evaded vaccine protection. By the end of 2023, protection against infection from the XBB.1.5 Pfizer booster was 35% (95% CI: 10–52%) among 18–59 year olds and 55% (95% CI: 48–61%) among 60–85 year olds (Huiberts *et al.*, 2024). Furthermore, for unknown reasons, COVID-19 vaccine protection quickly waned with time. While some vaccines, for example, measles and polio, confer lifetime immunity, COVID vaccines require annual updates and boosters every 6 months. Other than vaccinations, there are two other therapeutic approaches to avoid infection: monoclonal antibodies and 5% iodine nasal spray and/or gargle.

6.1.1. Monoclonal antibodies

The two that were approved for use to prevent COVID-19 infection in the US were Evusheld (tixagevimab and cilgavimab) and Pemgarda.

Levin *et al.* (2022) reported that at a median of 6 months after use, Evusheld reduced infection risk by 82.8% (95% CI: 65.8–91.4%). A meta-analysis by Glhoom *et al.* (2024) similarly found that Evusheld reduced COVID-19 symptomatic infection by 77%. Although it was effective against Omicron BA.1 and BA.2, later Omicron subvariants rendered it ineffective.

In August 2024, Invivyd, the manufacturer of Pemgarda, reported its phase III trial results. Through the first 6 months, there was an 84% infection risk reduction. Between months 7–12, there was a 64% risk reduction of symptomatic COVID in immunocompetent adults. However, variants KP.3.1.1 and XEC significantly impacted Pemgarda neutralization rates. Subsequent studies reported the same reduced effectiveness.

6.1.2. Povidone iodine nasal spray or gargle

Several pre-pandemic studies reported that 0.5–1% povidone iodine nasal spray or gargle killed all viruses in the nose or mouth. Fujii *et al.* (2006) reported that treatment of SARS-CoV-1 with povidone iodine products for 2 min reduced viral infectivity from 1.17 $\times 10^6$ tissue culture infectious dose to below detectable levels. Pelletier *et al.* (2020) reported that all evaluated concentrations of nasal antiseptics and oral rinse antiseptics completely inactivated SARS-CoV-2 after 60 s. Moreover, povidone iodine nasal spray resulted in an 8.57 times reduction of COVID-19 hospitalization and death rates (Baxter *et al.*, 2024).

6.2. NPIs

NPIs are techniques to avoid SARS-CoV-2 infection that are not based on vaccines or therapeutics. They are particularly important for immunocompromised individuals. Furthermore, diabetic individuals utilized them more than the population average.

There are two types of NPIs that keep viral particles from entering the body. First, elimination of SARS-CoV-2 before human contact by killing the virus on surfaces, on the skin, in liquids, or in the air. Second, avoid COVID-19 infection by staying away from infected people or animals and/or their viral particles.

6.2.1. Elimination of SARS-CoV-2 before human contact

There are several aspects to consider when eliminating the virus before it comes into contact with humans. This eradication encompasses the skin, hard surfaces, liquids, and air.

Killing the virus on the skin is relatively easy. Wash it with a good soap for 20 s or use an alcohol-containing disinfectant like Purell. However, these practices can induce irritant contact dermatitis, particularly in healthcare professionals, who often seek out skin-friendly cleansers to minimize irritation. In regard to hard surfaces, cleaning with a disinfectant such as bleach or Virusend not only kills the virus on the surface but also provides lasting protection for the surface.

Viral infection does not occur through the drinking of water, as one cannot get infected by ingesting solid foods or liquids. However, swimming pools can be the source of an infection. Brown *et al.* (2021) reported that to meet the United Kingdom's swimming pool regulations, infectious SARS-CoV-2 levels must be reduced by at least three orders of magnitude. A pH of no more than 7.4 and free chlorine above 1.5 parts per million achieved that goal.

COVID-19 primarily spreads through small, respiratory droplets. Hence, removing them from the air would serve as another method of eliminating the virus before it comes into contact with humans. There are several ways to achieve this. One way is using ultraviolet light. Liu and Shan (2023) reported that ultraviolet light kills viruses by disrupting their RNA. Hence, inexpensive ultraviolet systems can be installed in heating, ventilation, and air conditioning heating/cooling systems to inactivate viral RNA using human-safe, electromagnetic waves. However, ionization does not appear to be effective at killing SARS-CoV-2.

Installing high-efficiency particulate air (HEPA)-14 filters is another method which is eliminating the virus from the air. The SARS-CoV-2 virus is about 0.1 μm in diameter. HEPA-14 filters can remove at least 99.97% of airborne particles that are 0.3 microns (μm) or larger in size. Fortunately, if the air is passed multiple times through a HEPA-14 filter, it will remove the 0.1 μm SARS-CoV-2 particles from the air. Ueki *et al.* (2022) reported that an air cleaner with the HEPA filter removed SARS-CoV-2 from the air at virus capture ratios of 85.38%, 96.03%, and >99.97% at 1, 2, and 7.1 ventilation volumes, respectively.

Another important factor to consider is ventilation. During the pandemic, there have been more than 2,000 documented "superspreading" events, in which a single, infected person quickly infected many others. Almost all involved large groups in poorly ventilated indoor spaces. Morawska *et al.* (2024) reported key lessons learned from the COVID pandemic on ventilation's role as an effective means against airborne pathogen transmission. The authors highlighted the longstanding historical connection between air quality and infectious diseases. Moreover, Busato and Cavallini (2023) demonstrated the power of ventilation systems in school rooms. Interestingly, they only required 1/3 the energy to keep the Italian classrooms heated compared to open windows (Figure 4).

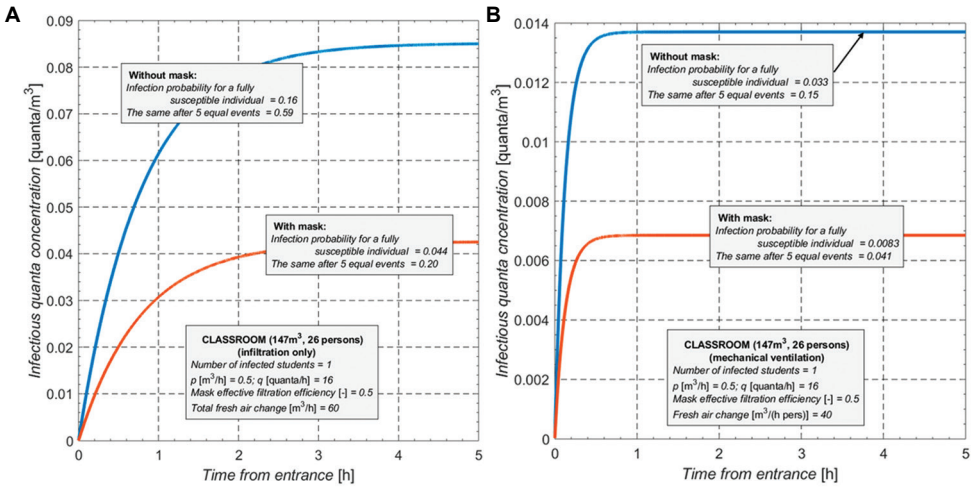

Figure 4. The power of air ventilation systems. (A) Open window and (B) mechanical ventilation infection rates. Image obtained from Busato and Cavallini (2023).

6.2.2. Protection from COVID-positive individuals

At the peak of the early 2022 Omicron surge, including asymptomatic cases, roughly 4% of the US population was infected. If you walked passed people on a street or were with a group of people, the likelihood of at least one of them being infected is shown in Table 3.

The risk of infection in an air-conditioned space was demonstrated by Lu *et al.* (2020) in a restaurant in Guangzhou, China, as shown in Figure 5. Among the 83 individuals in the restaurant, 10 were infected with COVID-19. The attack rate to those seated near the index case was ~23%. Small droplet aerosol transmission was implicated as viral spread occurred beyond six feet.

Given how easily it is to be infected through aerosol spray, it is evident why so many people got infected. There are actions one can take to reduce the chances of infection, but unfortunately, each has negative consequences. Table 4 summarizes the NPIs that were employed to avoid infection.

Other, less impactful forms of reducing the chance of infection were smart elevators, improved refuse shoots, spittoons, and virus-blocking textiles and fibers.

6.2.2.1. Border closures

During 2020–2021, nearly every country in the world imposed border restrictions to curb the spread of SARS-CoV-2. More than 1,000 new international border closures were introduced in 2020 and 2021. As shown in Figure 6 (African Center for Strategy Studies, 2020), it took the Spanish Flu 18 months to infect the world, mainly through World War I troop ships.

Even with the border closures, COVID-19 spread globally within 3 months—highlighting the speed of modern air travel compared to historical troop ship movements. Shiraef *et al.* (2022) found no evidence in favor of international border closures except in a few highly isolated countries, for example, New Zealand, Australia, and South Korea. Typically, attempting to close the borders only delayed the COVID-19 spread by a few days. Sometimes, partial closures had little effect. For example, when Trump closed the borders to China, he let infected Americans return home.

Airplanes were quickly recognized as high-risk environments for COVID-19 transmission, leading to a sharp decline in air travel. According to TSA passenger data, and after adjusting for population increases since 2019, US air travel per capita did not return to pre-pandemic (2019) levels until 2024. The 2023 population level adjusted traffic levels would have exceeded 2019 levels if people had followed the traditional Thanksgiving and Christmas heavy traffic patterns. However, the winter surge kept them home.

6.2.2.2. Testing and contact testing

Given that 60% of COVID-19 spread happens from asymptomatic infected people, the only way to be sure that someone does not have COVID-19 is to test them. While many next-generation tests are under development, the two personal pandemic testing workhorses were the polymerase chain reaction (PCR) and the rapid antigen tests. The third type of test, antibody, is used to see if someone was previously infected with COVID-19. Notably, only slightly more than 40% of the people who tested positive for prior infection were aware that they had been infected.

PCR is a laboratory technique that detects and amplifies specific genetic sequences, such as those in viruses and

Table 3. Infection probabilities

Number of people	Probability of at least one person having COVID (%)
10	33
20	56
30	71
40	80
50	87

Table 4. Techniques to avoid infection

Technique	Negative consequences
Border closures	Impeded worker movement and people returning home
Testing and contact tracing	Before rapid antigen tests, polymerase chain reaction tests were difficult to get and often took too long to provide an actionable result
Glasses or goggles	Goggles are uncomfortable, and some can fog up
Face masks	Masks are uncomfortable, interfere with recognition, and increase the chance of bacterial infection due to the warm, moist environment created by the face masks
Social distancing	It interfered with all aspects of daily life, for example, socialization, shopping, eating out, and working
School closures	They reduced learning, caused isolation, increased myopia, and increased body mass index
Lockdowns	They significantly interfered with all aspects of daily life and led to extreme isolation

bacteria. PCR testing is highly sensitive and can detect small amounts of genetic material. In PCR testing, a nose or throat sample is sent to a lab. One receives the test result as early as 24 h after the test, but it took several days when case rates were high and testing capacity was low. While PCR tests provided insights into case rates, their delayed results often precluded their use for behavior modification. South Korea, with its excellent, widely deployed camera face recognition technology, excellent test availability, and a compliant population, used PCR testing in its world-class contact tracing system to control viral spread.

In contrast, the rapid antigen test is an at-home, personally administered test with results returned in about 20 min. It detects the presence of the N protein, is quite accurate, and has yet to be affected by variants. It is used for determining if it was safe to visit friends or relatives, whether people could board an airplane or enter a country, if people should take an antiviral, and who should be isolated in a nursing home, prison, college, or passenger ship. Their widespread use reduced COVID cases, and the introduction of community testing was associated with a 43% (95% CI: 29–57%) reduction in COVID-related hospital admissions in Liverpool during the United Kingdom national lockdown from November 06 to December 03, 2020 (Zhang *et al*., 2022).

Contact tracing was only effective when case rates were low, testing was high, and the population was compliant, for example, South Korea. Due to the terribly botched CDC test development effort, the US did not have effective testing until mid-March 2020, and some states did not have enough tests until June 2020. Low test availability, high case rates, and the difficulty of getting some people to take tests made contact tracing useless in the US. Due to the high US case rates, the George Washington University Fitzhugh Mullan Institute for Health Workforce Equity contact tracing estimator estimated the US would have needed 1,250,000 people in the contact tracing workforce in September 2020 to be effective. A very clever use of testing was the US's Test to Treat program. If one tested positive, one could find a pharmacy from a website where s/he could get a free COVID antiviral such as Paxlovid.

Other forms of testing were used for special purposes. Pooled testing, when the samples of many people are mixed together, could, for example, determine if someone in a college dorm was infected. If so, individual testing could determine the infected individual. Wastewater testing was used to provide some indication of COVID case rates when home testing replaced lab testing. It started as a pandemic novelty and is now widely used around the world, for example, in Zambia and Ethiopia. Van Beusekon (2023) reported that more than 70 countries and 3,500 sites report COVID wastewater data to a global dashboard.

There were other forms of less frequently used tests, for example, dog sniffing. As the pandemic progressed, many next-generation tests were developed, enhancing existing tests or analyzing different properties such as lipid levels, sweat, or breath. These innovations used different measurement technologies such as magnetic nanoparticles, smart toilets, and smartphones. Some were wearable, such as face masks capable of performing on-the-go testing.

6.2.2.3. Glasses or goggles

There is a wide range of results on the impact of wearing glasses and goggles. Li *et al.* (2020) reported a much lower COVID-19 rate for those who wore glasses for 8 h a day. They speculated that the glasses reduced the hand-to-face touching and thus reduced the chance of infection. The study included 276 patients hospitalized with COVID-19 in Suizhou, China. The proportion of daily eyeglasses wearers who were infected with COVID-19 was much lower than that of the local population (5.8% vs. 31.5%).

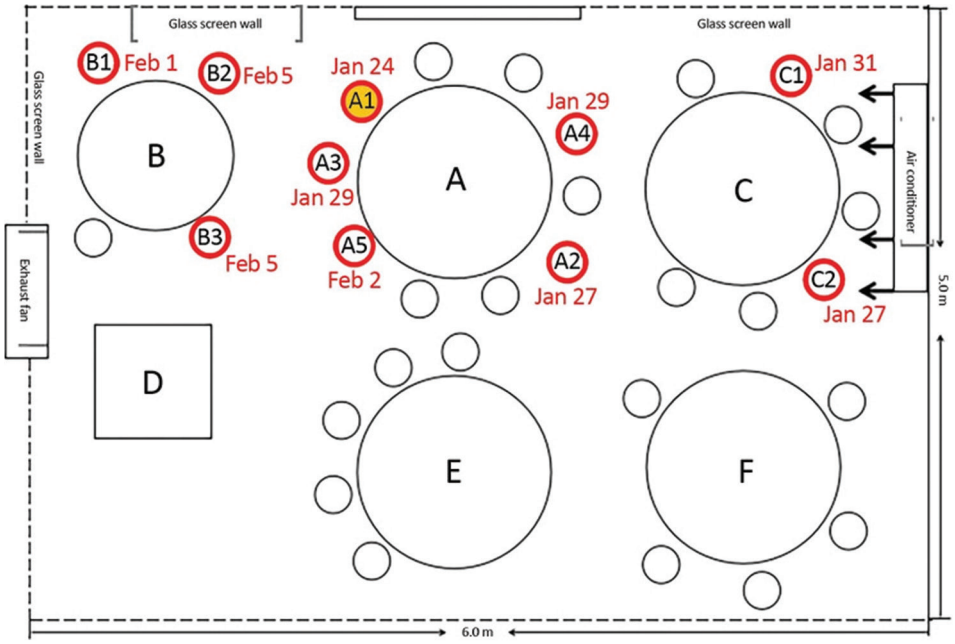

Figure 5. Guangzhou restaurant infections and positive testing dates. A1 refers to the index case. Image obtained from Lu *et al.* (2020).

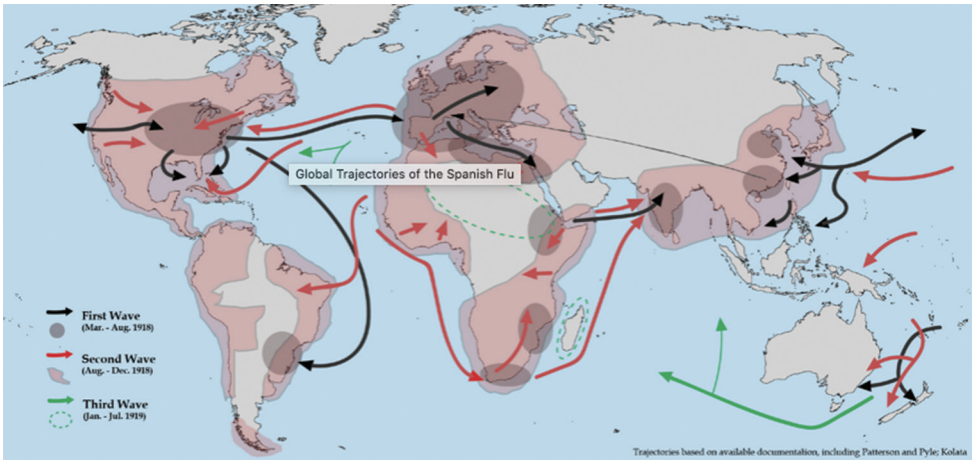

Figure 6. The spanish flu global spread. Image obtained from the African Center for Strategy Studies (2020). Source: https://africacenter.org/spotlight/lessons-1918-1919-spanish-flu-africa.

However, the paper did not discuss mask-wearing among the study participants.

All healthcare professionals should consider tears to be potentially infectious. They should ask patients about ocular symptoms consistent with COVID-19 and use eye protection such as goggles or face shields as part of the standard personal protective equipment.

6.2.3. Primary NPI measures

The primary NPI measures against COVID were face masks, lockdowns, school closures, and social distancing. Most US states mandated them, but over different timeframes and with different rules. Their duration and implementation by the Democratic and Republican states are summarized in Figure 7.

Akhmetzhanov *et al.* (2022) reported a significant reduction in the number of cases in Taiwan after the implementation of control measures. Figure 8 demonstrates the importance of acting early during the pandemic.

Krieger *et al.* (2022) reported that in models mutually adjusted for congressional district political and social metrics and vaccination rates, Republican and conservative voter political lean was associated with 11–26% higher COVID-19 mortality rate, as shown in Figure 9. The

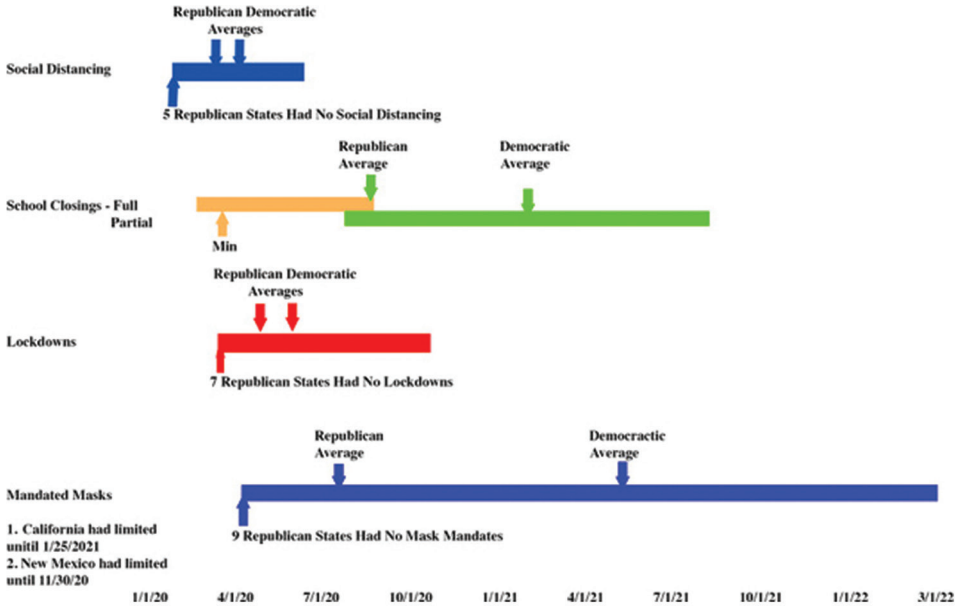

Figure 7. Primary COVID-19 nonpharmaceutical interventions timeframes

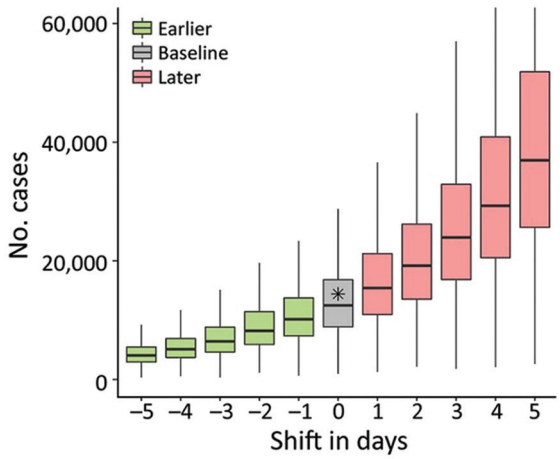

Figure 8. Impact of speed on COVID-19 case rate growth. Image obtained from Akhmetzhanov *et al.* (2022).

X-axis is the Democratic/Republican leaning based on the congressional representative's voting record.

If the death rates for the political parties had been the same, Trump would have won Arizona and Georgia in the 2020 Presidential election; however, he would have still lost the election to Biden. These differences were the result of the lack of mandates in some states, but also the lower Republican compliance with mandates. As shown in Figure 10, Republicans and Democrats behaved quite differently.

6.2.3.1. Face masks

Face masks have been around a long time. In the 1500s, European women wore them to be fashionable and to hide their identities. Pale skin was a sign of high status; sun-kissed skin suggested poor health, and the drudgery of working outside. To achieve the lightest complexion, untouched by freckles and sunburn, upper-class women wore face coverings to shield their faces from sun, wind, and dust. Wearing face masks was controversial during the 1918 Spanish pandemic.

Face masks were very effective during the Spanish flu. US cities that were strictly compliant in face mask wearing did not have a second Spanish Flu wave. The masks worked for severe acute respiratory syndrome and MERS, so why were they not strongly recommended in the US during the COVID-19 pandemic onset? Part of the reason was that the Strategic National Stockpile had only 12 million N95 masks. It had once held more than a hundred million masks, but many were used during the 2009 H1N1 flu pandemic, and the supply was not replenished. Dr. Fauci commented that he intentionally underplayed face masks early in the pandemic due to their short supply and medical personnel's urgent need. In April 2020, he told the American public that face masks would help stifle the pandemic.

In February 2022, *The New York Times* reported that the number of weddings in the US dropped in 2020, from

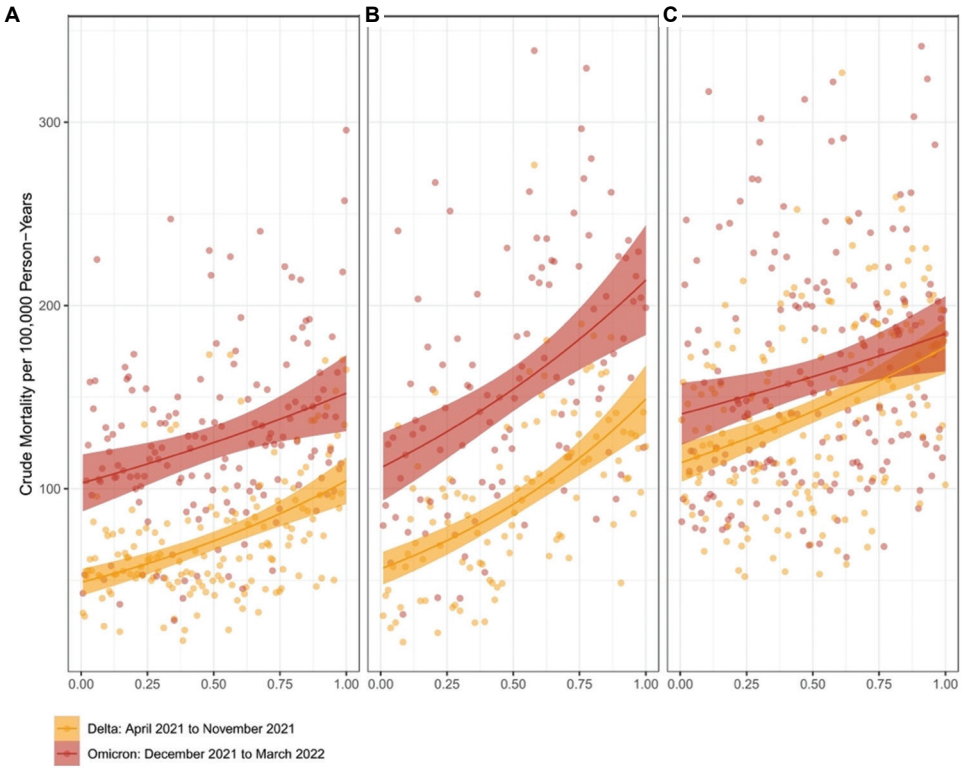

Figure 9. Impact of political bias on united states COVID-19 death rates. (A) Democratic: 14 states, with 151 congressional districts, (B) divided: 13 states, with 107 congressional districts, and (C) republican: 23 states, with 177 congressional districts. Image obtained from Krieger *et al.* (2022).

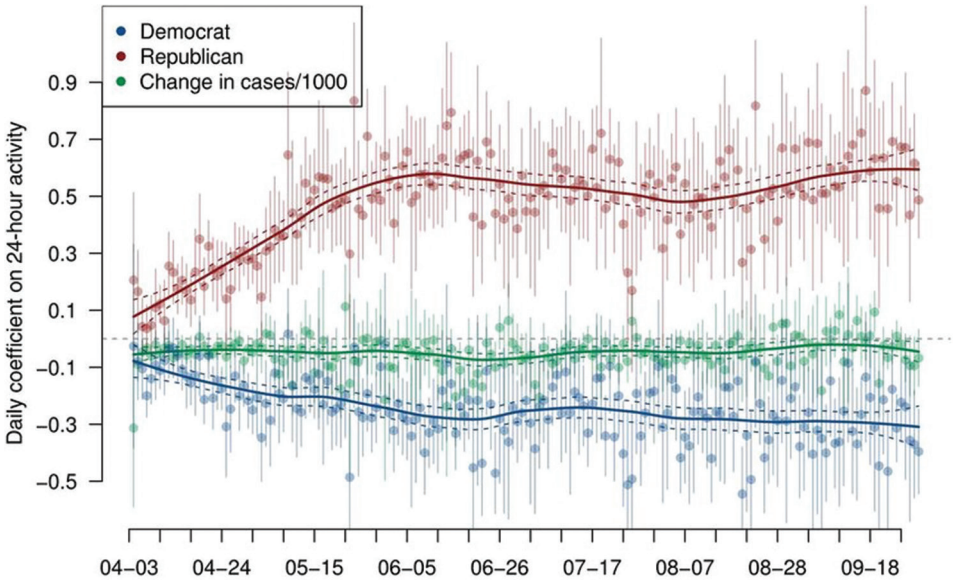

Figure 10. Mobility reduction rates based on politics. Image obtained from Clinton *et al.* (2021).

about 2.4 million per year to 1.4 million. While some ceremonies took place with masks, the drop in the number of weddings may have also contributed to the 4.39% drop in the birthrate observed in 2020 compared to 2019.

There are many types of face masks, with cloth, surgical, KN-95, and N-95 being the most common. Face masks reduced the spread of disease from people with COVID-19 and protected people from the infection. As

shown in Figure 11, there are huge differences in the ability of different masks to block aerosol droplets (Fischer *et al.*, 2020). For Omicron variants, surgical and cloth masks did not offer protection against infection, but still provided some protection against its spread.

Bagheri *et al.* (2021) reported mask effectiveness based on respiratory particle size, exhalation flow physics, leakage based on types and fits of face masks, ambient particle shrinkage due to evaporation, rehydration, inhalability, and deposition in susceptible airways. In Figure 12, "FFP2 w/o adjustment" is the same as a KN-95 mask, and "FFP2 with adjustment" is the same as an N-95 mask. There are two messages from Figure 12. First, surgical masks, even with adjusted straps, are not very effective. N-95 masks provide more protection than KN-95 masks because their straps facilitate a tight face fit. Second, when an infected person wears a mask, it provides slightly more protection than when an uninfected person wears a mask.

There were many studies on the effectiveness of wearing masks in reducing COVID-19 cases. The IHME

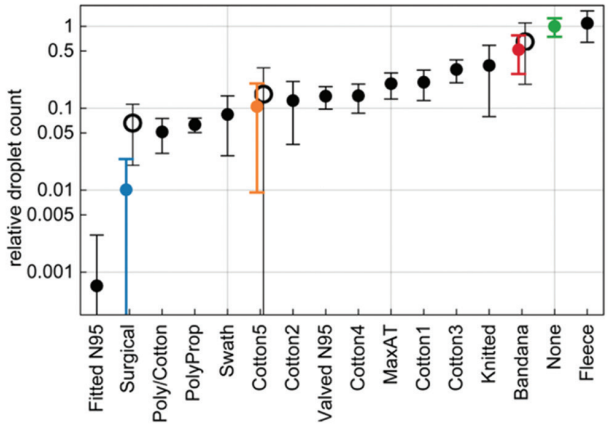

Figure 11. Mask relative effectiveness at blocking aerosol droplets. Image obtained from Fischer *et al.*, 2020.

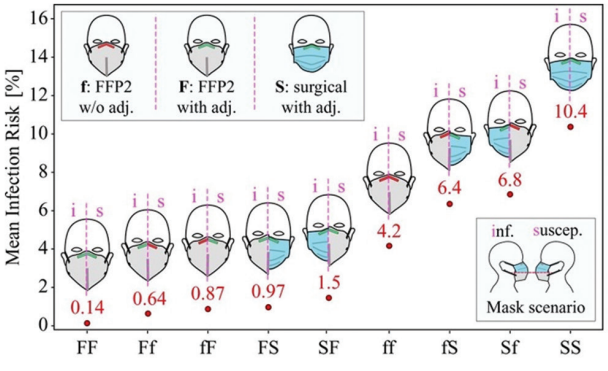

Figure 12. Infection risk from talking for 20 min while standing 1.5 m apart. Image obtained from Bagheri *et al.* (2021).

COVID-19 Forecasting Team (2020) reported a study that simulated the effect of mask wearing in the US. They reported that 470,000–580,000 people would die from COVID-19 by February 28, 2021, if states continued their present behavior of 49% of the population wearing masks. Significant lives would be saved from increased mask usage; 95% mask usage enabled 85,000–171,000 additional lives to be saved, while 85% mask usage enabled 61,000–133,000 additional lives to be saved. From Our World In Data, 520,000 died from COVID-19 in the US by January 28, 2021.

People of color wore masks more than White people. Nonetheless, due to poorer medical care and different jobs that had higher COVID-19 exposure rates, they had higher death rates. Budzyn *et al.* (2021) reported the mean county-level change in daily COVID-19 cases per 100,000 children and adolescents aged <18 years in counties with (198) and without (322) school mask requirements before and after the start of the 2021–2022 school year, as shown in Figure 13.

The most effective NPI after lockdowns was masks. Nonetheless, as discussed earlier, many people did not wear masks, particularly Republicans and the ultra-orthodox from many religions. An August 2020 PEW survey reported mask usage rates by political party, as shown in Table 5.

As noted earlier, Republican states had higher COVID-19 case rates and deaths than Democratic states. Part of this was due to the difference in mask mandates, which is illustrated in Figure 14.

However, masks also have negative consequences. They are uncomfortable, slightly hinder breathing (though they do not impede exercise), impair facial recognition, and reduce speech recognition due to the lack of visual cues. In addition, they can cause some skin problems, particularly in health professionals who use them often. Mohanty *et al.* (2024) noted that worldwide face mask usage reached 129 billion per month early during the pandemic. When discarded, they impacted the environment in many ways and complicated waste disposal.

6.2.3.2. Social distancing

Social distancing limits physical closeness and contact with other people to avoid catching or transmitting an infectious disease. The question, of course, is what is close? An 1896 droplet emission study (Flugge, 1896) of speech, coughing, or sneezing proposed a 1–2-m safe distance. It was based on the distance over which sampled, visible droplets containing pathogens stayed in the air. In the 1940s, close-up, still images of sneezing, coughing, or talking were added to the data. A 1948 study on hemolytic streptococci by Howard

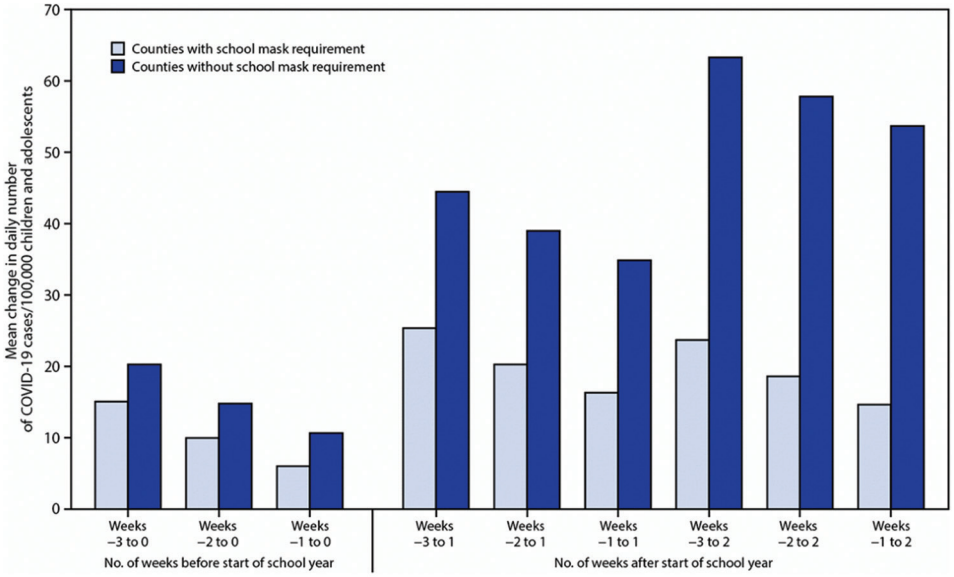

Figure 13. COVID case rates in the united states counties with and without mask mandates. Image obtained from Budzyn *et al*., 2021.

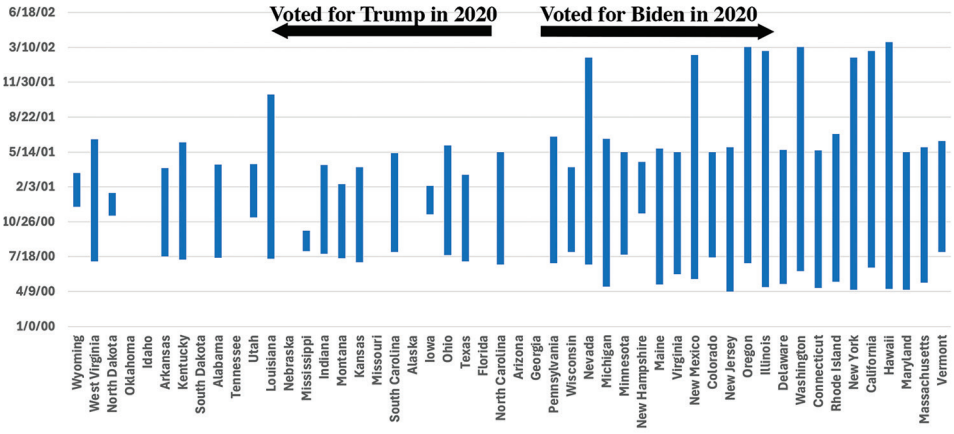

Figure 14. COVID-19 mask mandates. Data is ordered by increasing vote for biden in 2020.

Table 5. Percentage of people who wore face masks in 2020

Survey date	Democratic or Democratic leaning (%)	Republican or republican leaning (%)
June 2020	76	53
August 2020	92	76

et al. found that 65% of 48 participants produced only large droplets, with fewer than 10% of droplets traveling as far as 5.5 feet. However, 10% of droplets traveled 9.5 feet. Despite the limitations of these early studies—especially regarding long-range transmission—the consistent observation that large droplets tend to fall close to the host reinforced and entrenched the scientific basis for the six-foot distancing rule.

Thus, six feet appeared to be a reasonable minimum, but it must be modified based on factors such as whether one was indoors or outdoors, the nature of activities, crowd density, and whether someone without a mask was sneezing. The six-foot rule became obsolete when it was determined that aerosol droplets, which can linger and travel through the air, were the primary mode of COVID-19 transmission.

Fisher *et al*. (2020) provided additional insights into why social distancing was considered effective, as shown in Figure 15. Note the significant effect of being in crowded, active indoor spaces on transmission risk.

Each state had its own unique set of social distancing rules with varying strictness levels and exceptions. Typical

rules were closing non-essential businesses such as restaurants, bars, gyms, and churches. In certain instances, presenting a vaccination card—authentic or counterfeit—was sufficient to gain entry to restaurants, resulting in widespread use of counterfeit vaccine cards.

Price and van Holm (2020) reported that if the typical American individual were to spend 8 h away from crowds, there would be approximately 480,000 fewer COVID-19 cases. Courtemanche *et al.* (2020) reported that adoption of government-imposed social distancing measures reduced the daily growth rate of confirmed US COVID-19 cases by 5.4% after 1–5 days, 6.8% after 6–10 days, 8.2% after 11–15 days, and 9.1% after 16–20 days.

Social distancing compliance was influenced by political party and socioeconomic status. Regarding socioeconomic factors, Garnier *et al.* (2021) found that social distancing is less intense in counties with higher proportions of people below the poverty level and higher numbers of essential workers. In contrast, social distancing is intensely adopted in counties with higher population densities and larger Black populations, as shown in Figure 16.

Allcott *et al.* (2020) reported that researchers used location data from smartphones to show that areas with more Republicans engaged in less social distancing. The study controlled for other factors, including public policies, population density, and local COVID-19 cases and deaths. The paper also presented survey evidence of the significant gaps at the individual level between Republicans and Democrats in self-reported social distancing, beliefs about personal COVID-19 risk, and beliefs about the future severity of the pandemic. Figure 17 shows the social distancing by state.

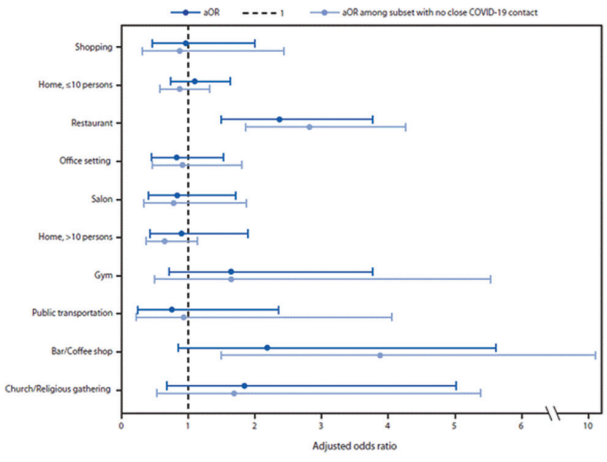

Figure 15. Relative odds of contracting COVID. Image obtained from Fisher *et al.*, 2020.
Abbreviation: aOR: Adjusted odds ratio.

6.2.3.3. School closures

School closures were and have remained the most controversial actions taken to reduce COVID-19 spread. The logic of its implementation is direct; schools are often crowded and poorly ventilated. They are a near-perfect COVID-19 spreading setting, particularly when singing the national anthem. Not only would the virus spread amongst the kids but it would also infect the teachers, the teachers' family members, and the children's family members. Figure 18 shows the rate of school closures by state.

The impact of school closures on COVID-19 case rates was difficult to analyze was schools could have taken many actions to reduce viral spread, for example, open the windows, install HEPA-14 filters, move desks six feet apart, mandate vaccination, initiate contact tracing, offer/or require diagnostic testing, and ensure everyone wore face masks.

Castillo *et al.* (2021) reported that daily COVID-19 infection rates were examined before and after statewide school closure orders. In the 15 states where data were available for 11 or more days after school closure, the average case rate drop was 25%; however, there was great variation in the case rate drop.

When the schools reopened, actions could be taken to reduce transmission risk. Weng *et al.* (2023) analyzed eight school operating scenarios. When masks were worn at school, work, and in the community, cumulative infections would have increased only 1% from increasing in-person education from 50% to 100%. As shown in Figure 19 and Table 6, when there were neither masks nor contact tracing when schools were conducted 100% in-person,

Table 6. Scenarios used to assess the impact of school reopenings

Scenario	In-person (%)	Remote (%)	Mingled with another class	Masks	Contact tracing[a]
1	50 alternating		No	Everywhere	Yes
2	50[a]	50	No	Everywhere	Yes
3	80[a]	20	No	Everywhere	Yes
4	100		No	Everywhere	Yes
5	100		Yes	Everywhere	Yes
6	100		Yes	Not at School	Yes
7	100		Yes	None	Yes
8	100		Yes	None	No

Note: [a]Contact tracing was difficult in the United States due to its high case rates. That said, focused contact tracing, perhaps, was implemented.

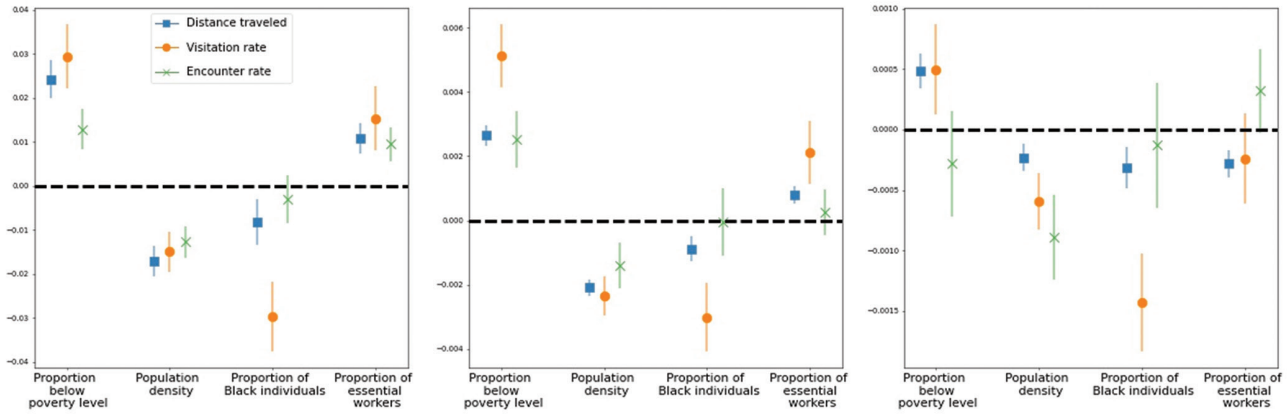

Figure 16. Impact of socioeconomic factors on the impacts of social distancing. Image obtained from Garnier *et al.* (2021).

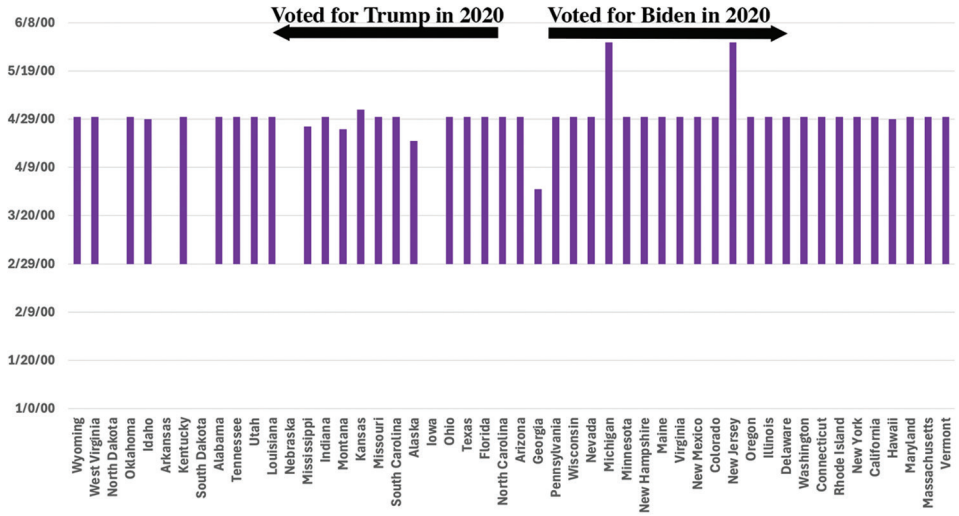

Figure 17. Social distancing practices by state. Data are ordered by increasing biden's vote in the 2020 election.

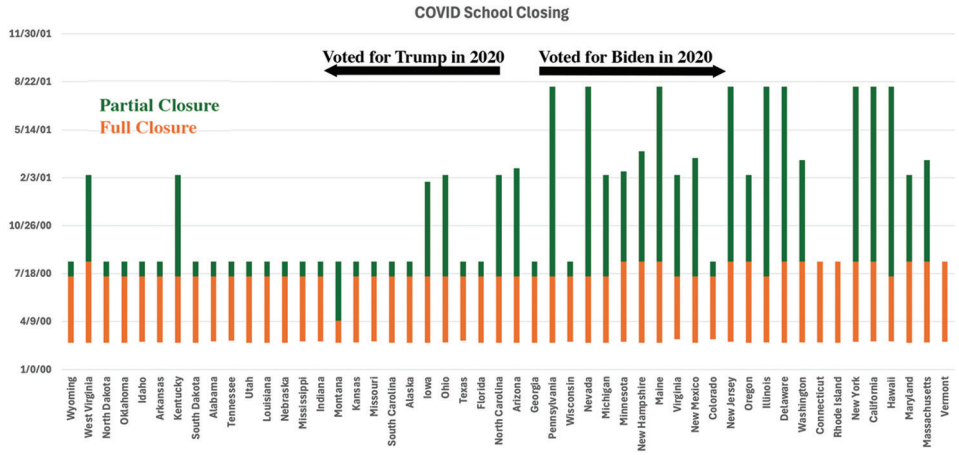

Figure 18. COVID school closures by state. (Ordered by increasing biden vote in the 2020 election). Image created by the author.

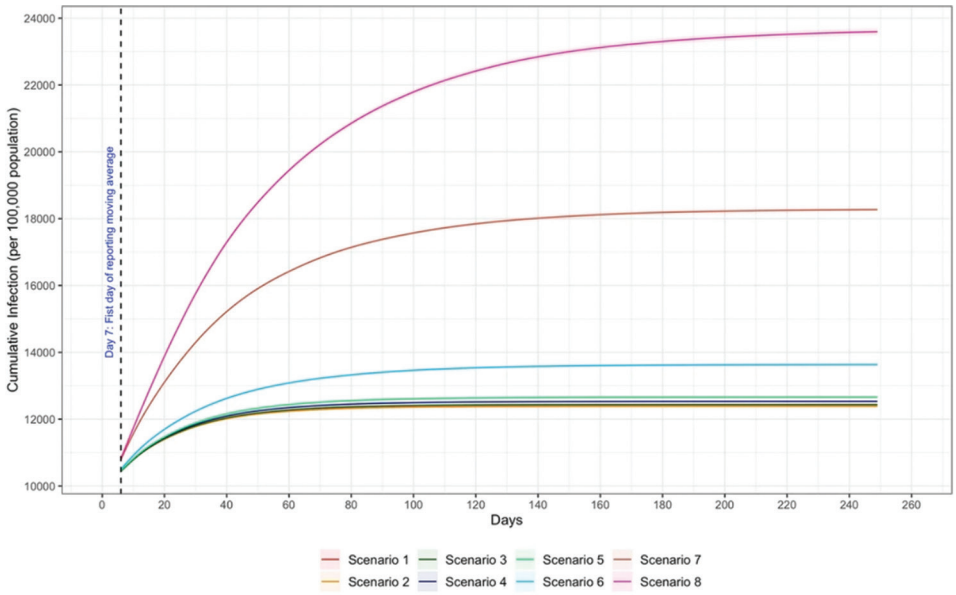

Figure 19. Impact of school reopenings under different scenarios. Image obtained from Weng *et al.* (2023).

the cumulative infection rate increased by 86%. Due to the existing vaccine hesitancy, the model assumed the maximum vaccination coverage of 70% for adults and 40% for children.

Rauscher and Burns (2021) reported that within nearest neighboring pairs in different states with different school closure timing, each additional day from a county's first case until state-ordered school closure was related to 1.5–2.4% higher cumulative COVID-19 deaths per capita. This was 1,227–1,972 additional deaths for a county with a median population and deaths/capita. A similar impact on death rates was reported by Viner *et al.* (2020), which addressed the COVID-19 outbreak in Hong Kong and China. They also reported that modeling studies of SARS-CoV-1 produced conflicting results. Auger *et al.* (2020) reported that closing schools when the cumulative incidence of COVID-19 was in the lowest quartile compared with the highest quartile was associated with 128.7 fewer cases per 100,000 population over 26 days and 1.5 fewer deaths per 100,000 population over 16 days.

Van den Berg *et al.* (2021) conducted a study on 251 school districts, 537,336 masked students and teachers, and found similar infection rates for three feet or six feet distancing, as shown in Figure 20. The CDC changed its school social distancing guidance on March 20, 2021, from six feet to three feet.

School closures, particularly when combined with lockdowns and social distancing, led to increased rates of mental illnesses in children. Moreover, they significantly impacted reading and math skills. Sadly, little to no progress

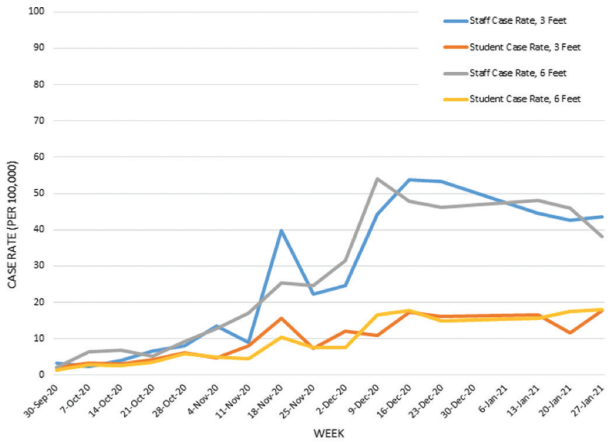

Figure 20. Three feet versus six feet social distancing in schools. Image obtained from van den Berg *et al.* (2021).

was made in 2024 to close the learning gap, as shown in Figure 21 from the National Assessment of Educational Progress (NAEP, 2023).

Global mathematics scores declined by an average of 14% of a standard deviation, roughly equal to 7 months of learning. Losses are greater for students in schools that faced relatively longer closures, for boys, immigrants, and disadvantaged students. Given the different school closure rates in Republican and Democratic states, one might expect that the Republican states had fewer educational drops. The simple correlation shown in Figure 22 supports this expectation.

Alarmingly, the school closures also affected the children's IQ according to a large German study

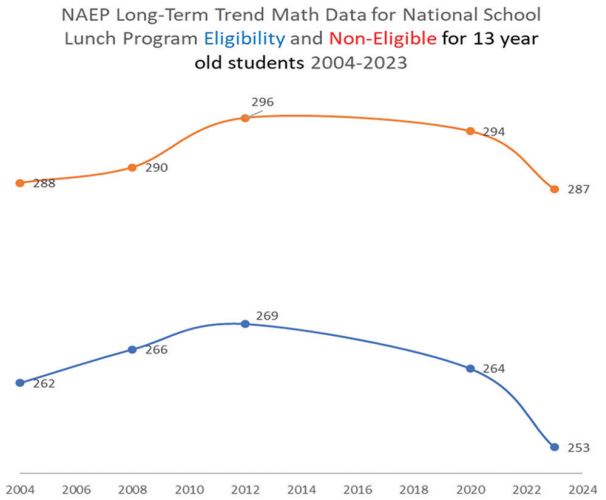

Figure 21. Drop in 13 year olds' math and reading scores. Image obtained from national assessment of educational progress (NAEP, 2023).

(Breit *et al.*, 2023). Similarly, the National Center for Education Statistics, May 2022 School Pulse Panel survey of US public K-12 schools showed that the COVID-19 pandemic, continued to significantly impair student socioemotional and behavioral development. During the most recent school year, over half reported that chronic absenteeism was worse than the year before, as shown in Figure 23.

There were other impacts from school closures, such as increased body mass index, increased myopia from more video games, reduced fitness, and higher rates of cyberbullying and teenage pregnancies.

6.2.3.4. Lockdowns

The most severe NPIs were lockdowns/stay-at-home orders, where individuals were supposed to stay at home except for obtaining essential services such as food shopping and medical care. As shown in Figure 24, five Republican states did not have lockdowns. The average length of their implementation in Democratic states was 57 days. In the Republican states that implemented lockdowns, it was 35 days.

Altoè *et al.* (2020) reported the impact on lives saved by advancing or delaying lockdowns in Belgium, Hubei, China, Denmark, Germany, Italy, Korea, New Zealand, the United Kingdom, and the US by ±3 days. Notice the lives saved represent more than twice the lives lost to COVID-19 in the US through 2024, as shown by Table 7.

There were some positive impacts from lockdowns. Zheng *et al.* (2025) reported that global pollution dropped, as shown in Figure 25. The drop in air pollution was accompanied by dropping disease rates, particularly diseases related to the ears, throat, and lungs (Altoè *et al.*, 2020).

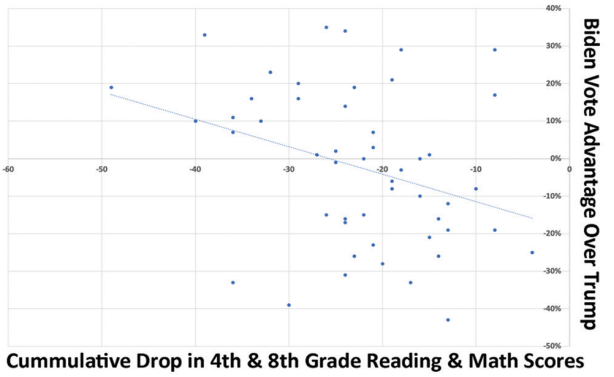

Figure 22. Cumulative drop in fourth- and eighth-grade reading scores by Biden's vote advantage over Trump

Table 7. Number of lives saved through lockdowns

Country	Saved by lockdown (*n*)	Three days earlier		Three days later	
		Number	Percentage	Number	Percentage
Belgium	71,000	4,600	6.5	7,700	10.8
China (Hubei)	67,000	2,200	3.3	4,000	6.0
Denmark	35,000	300	0.9	500	1.4
Germany	539,000	4,000	0.7	7,900	1.5
Italy	378,000	18,100	4.8	29,100	7.7
Korea	276,000	105	0.0	182	0.1
New Zealand	30,000	37	0.1	72	0.2
United Kingdom	424,000	20,000	4.7	32,000	7.5
United States	2,283,000	51,100	2.2	90,000	3.9
Cumulative	4,103,000	100,442	2.4	171,454	4.2

Trajtenberg *et al.* (2024) reported that cities that implemented strict lockdowns experienced large declines in robbery, burglary, and vehicle theft, but assault, theft, or homicide increased, as shown in Figure 26.

Businesses such as restaurants, bars, gyms, and even churches in some states were shut down. Salpini (2021) noted that witnessing the pandemic's impact on retail was equivalent to watching a series of waves wash over the industry. When the pandemic began, retailers were not sure exactly how long-lasting the crisis would be. Retail Dive kept a tracker that evolved into a living journal of how retailers were responding to 2020's unique events. In addition, even babies were affected. With reduced socialization, their speech development lagged, as shown in Figure 27 (Bartelt *et al.*, 2025).

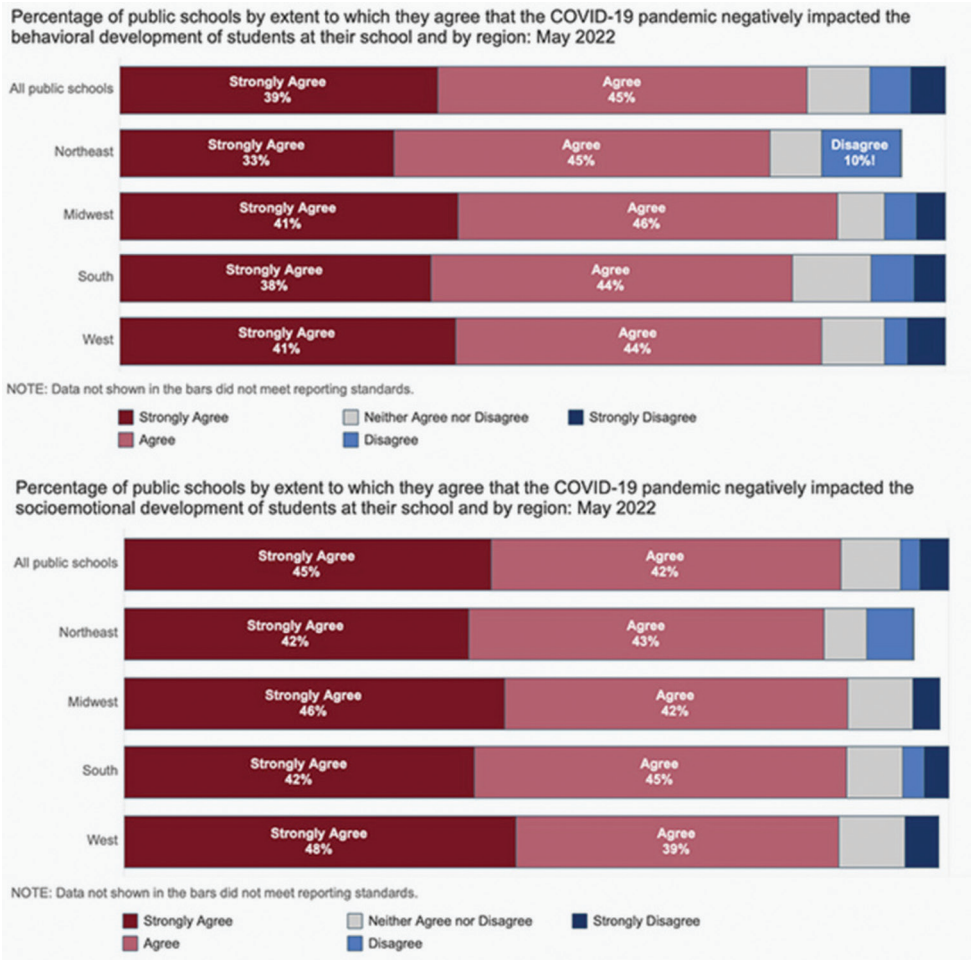

Figure 23. Public schools that agreed that COVID-19 impacted emotional development. Image obtained from Malkus (2024).

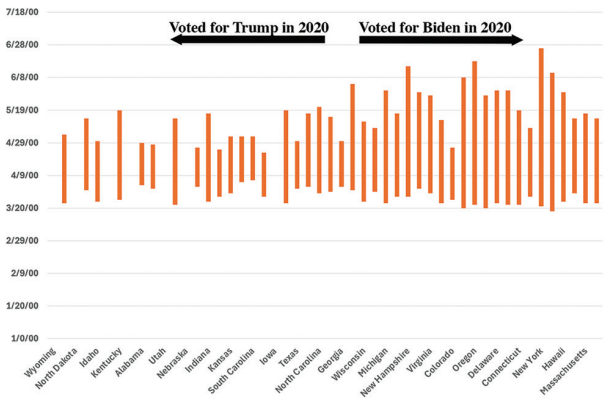

Figure 24. COVID-19 lockdowns. Data are ordered by increasing Biden's vote in the 2020 election.

Virtual meetings were used for work, education, medical services, shopping, socialization, and entertainment. In each of these domains, the impacts were diverse. For example, in education, beyond the drop in test scores, cheating, youth arrests, and absenteeism increased. There were socioeconomic differences in all of these impacts. With virtual work, people fled the cities.

Some businesses thrived during the pandemic. A notable example is Instacart, where one places an order online, which is filled by an "Instacart Shopper," who would deliver your food. Amazon, DoorDash, Fresh Direct, Uber Eats, and many others provided similar services. Instacart has about a 73% market share of the door delivery services market. Perhaps unexpectedly, the pandemic permanently changed food home delivery and virtual communication rates.

While lockdowns saved lives during the pandemic, Bianchi *et al.* (2023) modeled the impact of COVID and estimated that lockdowns would lead to 800,000 future lives from the children of those saved during the pandemic. Lockdowns also had an economic impact as people could not work and often lost their jobs. Overall, the Republican-led states had a better economic recovery than the Democratic-led states, as shown in Table 8. This was, perhaps, a ripple effect of fewer and shorter lockdowns.

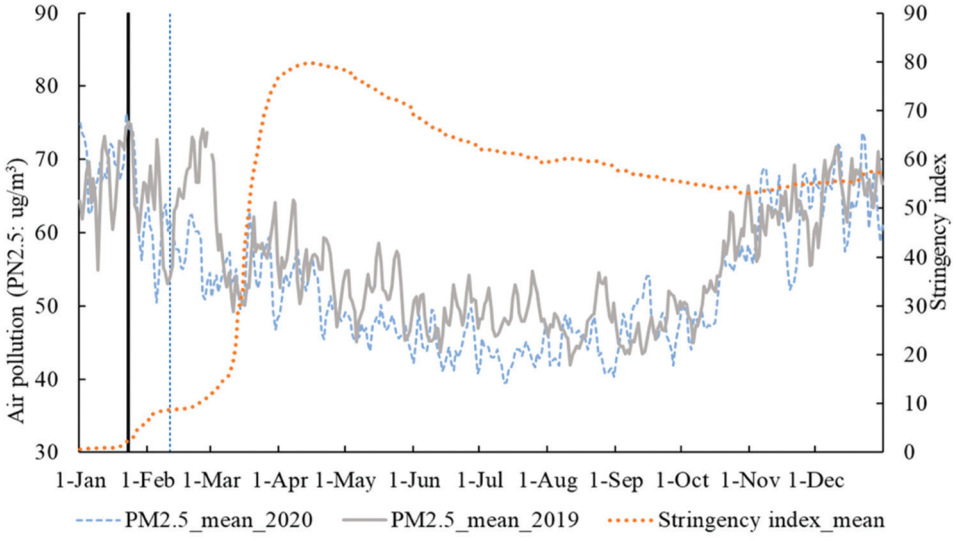

Figure 25. Global pollution and the stringency index. Image obtained from Zheng *et al.* (2025).

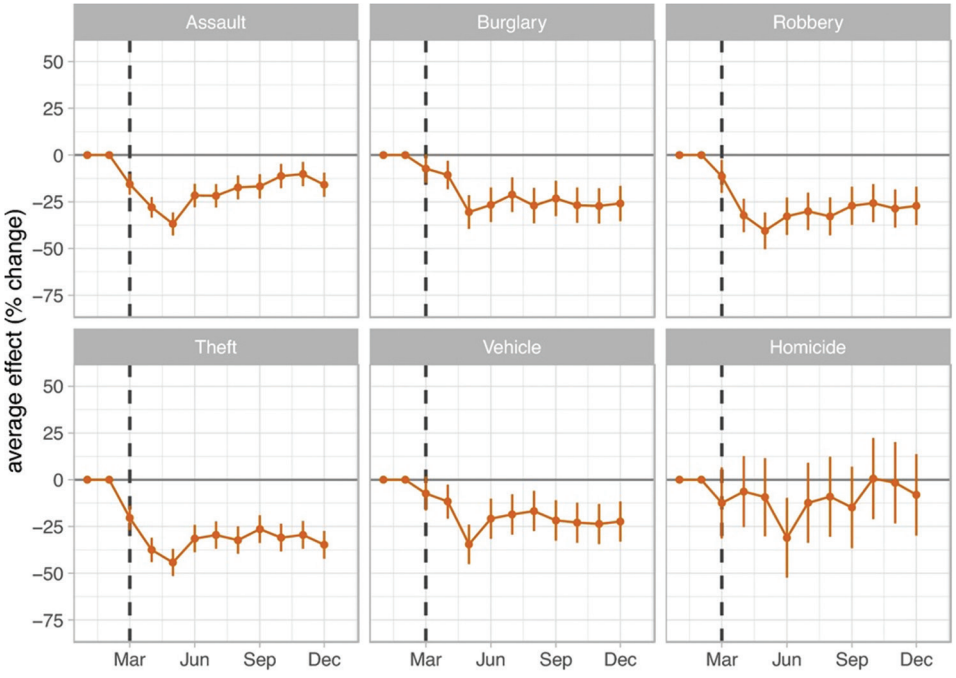

Figure 26. 2020 crime rate changes. Image obtained from Trajtenberg *et al.* (2024).

Table 8. Summary of state job recoveries

Parameters	Republican-led states	Democratic-led states
States with >100% job recovery	12	3
Average jobs recovered (% of jobs lost)	143%	118%
Average unemployment rate	3.4%	3.9%
States with record-low unemployment rates	3	0

Some states had yet to recover lost jobs as of April 2025, including California, Hawaii, Illinois, Maryland, Massachusetts, and New York, which are all Democratic-led states.

7. Pandemic medical impacts

Excess deaths that resulted from the COVID-19 NPIs have been discussed. Other COVID pandemic medical impacts were surprisingly broad-based and intense.

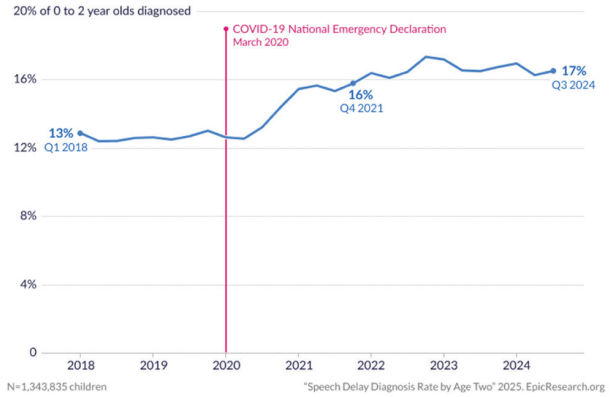

Figure 27. Speech delay in 2-year olds. Image obtained from Bartelt *et al.* (2025).

7.1. Stress

Fear of COVID for oneself, family members, and friends, unemployment, economic uncertainty, and the suppressive NPIs contributed to an increase in stress levels. An American Psychological Association report (2020) stated that despite several months of acclimating to COVID's societal upheaval, Americans were struggling to cope with its disruptions. A total of 78% said that the pandemic was a significant source of stress in their lives, and 67% said that they had experienced increased stress over the pandemic's course, as shown in Figure 28. The report stated that stress was greater in socioeconomically disadvantaged groups. Other reports noted that there were disproportionate effects on healthcare workers and chaplains.

7.2. Isolation and loneliness

Humans are inherently social animals. Preventing COVID-19 infection largely meant avoiding other people. Cudjoe and Kotwal (2020 [p.27]) noted that, "Decades of observational studies have demonstrated the long-term negative health outcomes of social isolation and loneliness. The COVID-19 crisis has exacerbated these challenges, with worsening social isolation and loneliness among those who live alone or are frail and even declines in the well-being of older adults with previously active or healthy social lives. Community centers for older adults have closed, nursing homes have terminated visitation, and grandparents are unable to visit their grandchildren."

The book, *Loneliness*, notes that loneliness impairs executive function and that there are genetic predispositions to loneliness (Cacioppo & Patrick, 2008). It also stated that it modulates some of the same neurochemicals involved in depression, such as serotonin, oxytocin, and vasopressin. Likewise, inflammation, which is one of COVID's dangerous outcomes, can be triggered by loneliness and

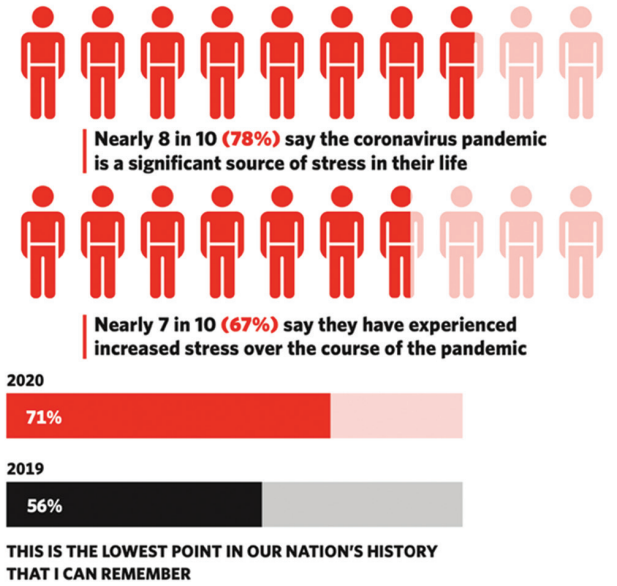

Figure 28. Pandemic and stress. Reprinted with permission from American Psychological Association (2020). Copyright © 2025, American Psychological Association.

isolation, physical inactivity, chronic stress, poor sleep, and negative thought patterns.

While loneliness affected everyone during the pandemic, those with dementia were particularly severely affected. Chen *et al.* (2023) reported excess deaths attributable to dementia, as shown in Figure 29.

Lockdowns, of course, were key contributors to loneliness, particularly among seniors who did not have access to the internet or regular companionship from children, grandchildren, or pets. Caring for grandchildren or pets helped in coping with loneliness; however, if one could no longer care for them, loneliness increased. Internet usage was more nuanced. If it was obsessively used to check on the pandemic, interestingly, loneliness increased. Loneliness also contributed to low physical activity, which, by itself, impacts health.

Moreover, loneliness triggered the "pandemic puppy" epidemic during which 20% of American households adopted a pet, which is equivalent to 55 million. Interestingly, most studies reported that they did not help with loneliness. The return rate for them was about the same as the return rate for prepandemic adoptions.

Isolation was not always bad. During his isolation from the Black Plague, Newton discovered differential and integral calculus, formulated a theory of universal gravitation, explored optics, experimented with prisms, and investigated light. He wrote the most important book in the history of science, Principia.

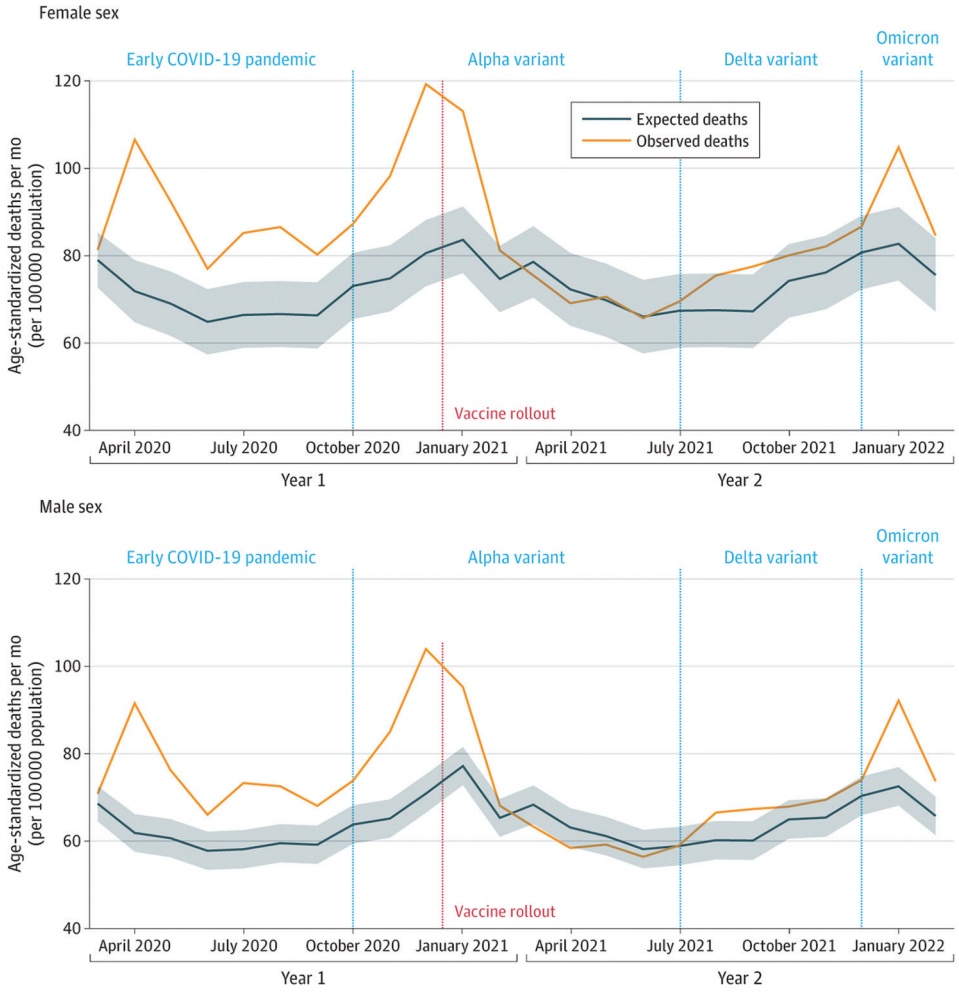

Figure 29. Excess dementia deaths. Image obtained from Chen *et al.* (2023).

7.3. Deaths of despair (DoD)

With increased stress and loneliness, DoD significantly increased in 2020. Entrup *et al.* (2023) reported that in 2020, COVID-19 caused 350,831 deaths and 4,405,699 years of life lost (YLL). By contrast, DoD contributed to 6,045,819 YLL. There were more YLLs in DoD because COVID-19 mainly killed the old, and DoD happened across all ages. Men had more deaths and YLL than women due to COVID-19 and DoD. Among White Americans and those with more than one race identification, both had a greater burden of DoD YLL than COVID-19 YLL. However, for all other racial categories (Native American/Alaskan Native, Asian, Black/African American, Native Hawaiian/Pacific Islander), COVID-19 caused more YLL than DoD. Surprisingly, as in Australia and New Zealand, the number of suicides in the US did not increase. They, however, did so in Japan, South Korea, India, Mexico, and Thailand.

The total number of US DoD in 2020 was 377,000, about 20,000 higher than the number of 2020 US COVID-19 deaths. Moreover, as COVID deaths were more prevalent among the elderly, the YLL from DoD in 2020 were greater than those lost to COVID-19, as shown in Figure 30.

7.4. Mental health

It is important to remember that there is a bias risk in survey questions, particularly about maladies that do not have definitive medical tests. It is hard to imagine someone replying negatively in October 2020 to a question like: "Are you more anxious and/or depressed than you were a year ago?" That said, many studies reported increased rates of anxiety and depression during the pandemic. Santomauro *et al.* (2021) reported a meta-analysis of 48 studies published between January 01, 2020, and January 29, 2021, as summarized in Figure 31. The increases in rates during the pandemic for various mental health problems are shown by pink relative to purple.

Not surprisingly, the mental health of those with severe comorbidities such as Parkinson's, lupus, inflammatory bowel syndrome, kidney diseases, eating disorders, or acquired immune deficiency syndrome was more significantly impacted. Those who exercised, were vaccinated, were religious, had positive lifestyles, for example, no smoking, low alcohol, and low body mass index, were less impacted. Misinformation increased mental health problems, as well.

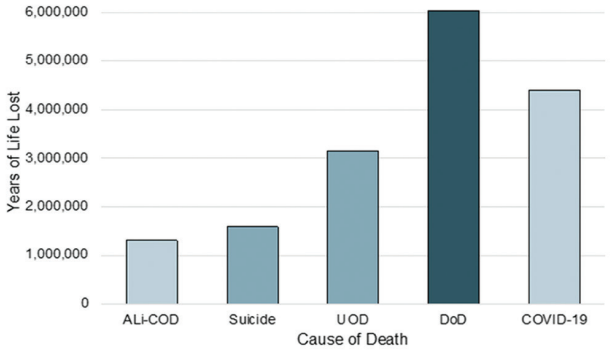

Figure 30. Years of life lost due to COVID-19 and deaths of despair, including alcohol-induced causes of death, suicide, and unintentional drug overdose in the US in 2020. Image obtained from Entrup *et al.* (2023).

7.5. Postponed treatments

Widespread delays in medical treatments during the pandemic have created serious long-term health risks. People were hesitant to go to crowded medical facilities. Furthermore, there were fewer doctors and nurses. Lack of medical insurance also impacted the socioeconomically disadvantaged. Figure 32 summarizes elective surgery rates in the US as reported by Butler *et al.* (2021).

7.5.1. Cancer

Although there were increased death rates for many diseases, for example, diabetes, cardiovascular diseases, and kidney disease, cancer had some of the largest increases. Thus, cancer will be used as an illustrative case for the impact of postponed health care during the pandemic.

Butler *et al.* (2021) reported that cancer screening rates were reduced by 70–80% in May 2020. This left a long-term impact on future cancer rates. They recovered to prepandemic rates only in February 2023. Angelini *et al.* (2022) observed that the risk of death from colon cancer from delayed treatment increased 6% for every 4 weeks that surgery was delayed, and that similar delays in adjuvant chemotherapy for colorectal cancer elevated the

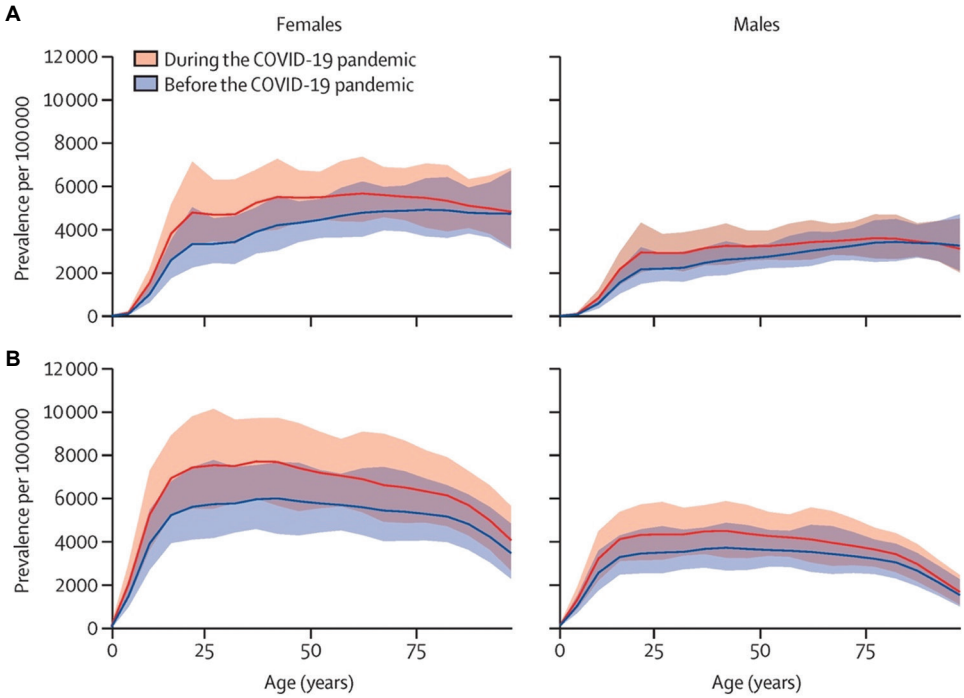

Figure 31. Global prevalence of major depressive disorder (A) and anxiety disorders (B) before and after adjustment for (i.e., during) the COVID-19 pandemic, 2020, by age and sex. Image obtained from Santomauro *et al.* (2021).

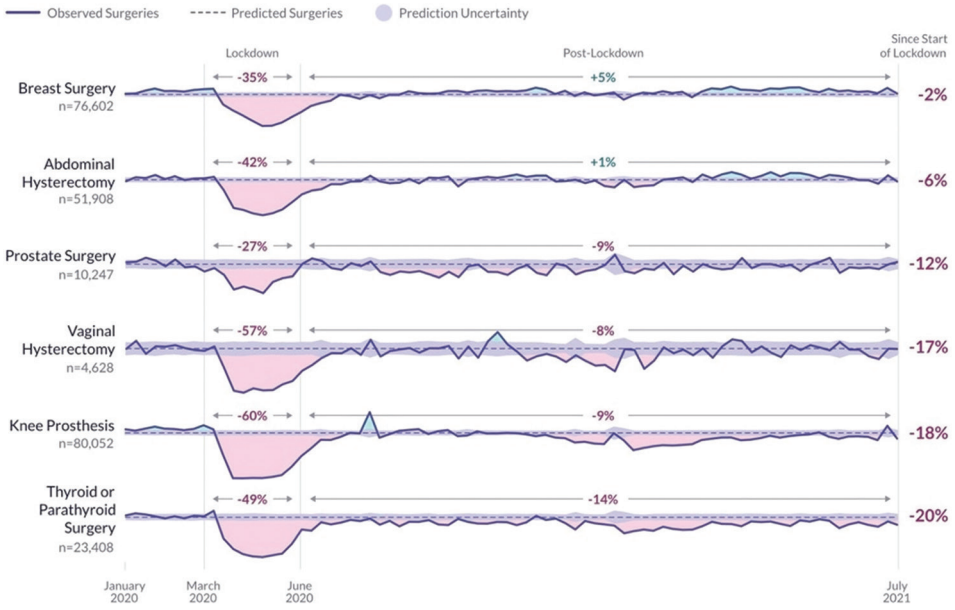

Figure 32. United states elective surgery rates. Image obtained from Butler *et al.* (2021).

mortality risk by 13%. Furthermore, the lack of screening and postponed treatments will lead to increased cancer deaths over the next decade, as shown in Figure 33 (Miller *et al.*, 2021).

7.5.2. Vaccination rates

An alarming case of postponed health care was the drop in non-COVID vaccines. They dropped early in the pandemic but have largely started to recover. Measles and polio vaccination rates are discussed to illustrate the impacts of delayed vaccination.

Measles is thought to have killed 150 million people over the past 150 years. It is highly contagious and is particularly dangerous to young children, who often die from pneumonia. The death rate in developed countries is 0.1–0.2%, while, in underdeveloped countries, it is 10%. Before widespread vaccination from the 1963 measles vaccine, there were an estimated 2.6 million annual measles deaths, mainly in underdeveloped countries, indicating that almost everyone had childhood measles.

A Johns Hopkins Public Health report (2024) stated that as of March 21, 2024, 64 measles cases were reported in the US, more than the 58 cases reported in all of 2023. More than 300,000 cases were reported globally in 2023, which is an increase of more than 79% from the previous year. More than 61 million doses of measles-containing vaccine were postponed or missed between 2020–2022 due to COVID-related disruptions. The World Health Organization stated that more than half the world's

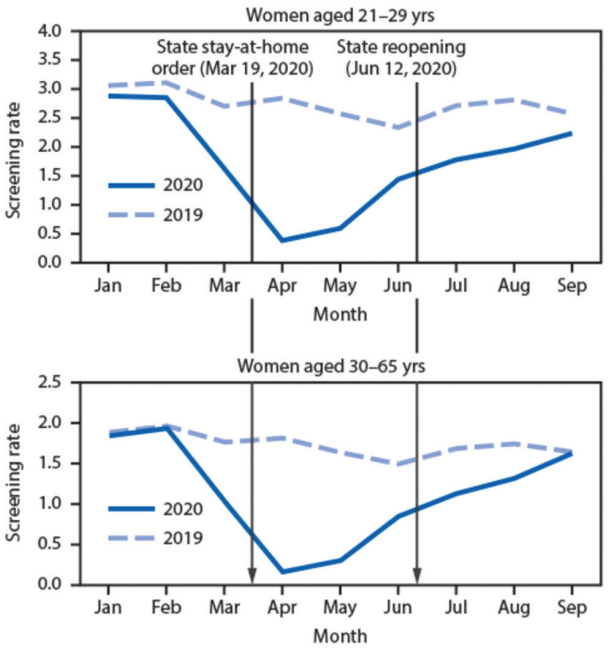

Figure 33. Delayed cervical screening rates in Southern California. Image obtained from Miller *et al.* (2021).

countries will be at high or very high risk of measles outbreaks by the end of 2023 unless urgent preventative measures are taken.

Polio was almost eradicated. In the early 1950s, polio was paralyzing or killing over half a million people worldwide annually. As a disease carried only by humans,

it became highly controllable with the introduction of the effective oral vaccine in 1961, though it can infrequently result in polio in a person who was recently vaccinated. It is called vaccine-associated paralytic poliomyelitis; however, this is very rare. For every million doses of oral poliovirus vaccines, there have been between 0.09 and 25 cases of vaccine-associated paralytic poliomyelitis. Hence, it is no longer used in any country. Instead, the inactivated version given through a needle and syringe is used. Figure 34 shows vaccine-induced polio cases.

Polio was eliminated from the US in 1979 and from the Western Hemisphere in 1991. However, the pandemic caused a reduction in vaccination and the growth of endemic cases in a few countries. Similarly, tuberculosis treatments have been set back at least a decade, cholera was on the rise, particularly in Pakistan and Bangladesh, malaria cases and deaths grew in 2020, and human immunodeficiency virus preventative programs and prescriptions decreased.

7.6. Disease prevalence changes

Not surprisingly, as reported by Cohen *et al.* (2022), NPIs reduced the rate of many pediatric viral infections in France. Lockdown strictness impacted the rate of decline. CDC reported (2023) that the rate of sexually transmitted diseases in the US went down significantly early in 2020, only to sharply rebound as restrictions were lifted and casual sex resumed.

Fortunately, the rate of many of the seasonal respiratory infections dramatically dropped, mainly from isolation, but also partially due to COVID-generated antibody and T-cell protection. The most significant reduction in disease prevalence is that of the seasonal flu. Chen *et al.* (2024) reported that the pandemic reshaped global flu patterns. For example, the US had only 624 flu cases in 2020. Furthermore, one strain, B/Yamagata, disappeared and is no longer included in flu vaccinations.

Other disease prevalence changes include respiratory syncytial virus, pneumococcus, noroviruses, scabies, conjunctivitis, Graves' disease, and hand, foot, and mouth disease. Similarly, human immunodeficiency virus treatment was reduced.

8. Weird behaviors

The pandemic triggered unfortunate and weird human behaviors.

8.1. Guns

Chen *et al.* (2023) reported firearm sales and gunshot emergency room visits before and during the 1st year of the pandemic. Although we were under lockdown during part of 2020 and encouraged to follow social distancing throughout 2020, both measures showed increments.

8.2. Wildfires

Chen *et al.* (2023) reported that the 2020 US western wildfires were at an all-time high, mainly due to increased recreation during a dry season.

8.3. Conspiracy theory and misinformation

Misinformation and conspiracy theories, often from the ultra-right, addressed, with hurricane force, COVID's source, NPIs, therapeutics, and vaccines. Many had deadly consequences, such as lower vaccination rates and improper therapeutic use, for example, hydroxychloroquine and ivermectin, used to treat COVID. Some examples of misinformation include:

(i) A PEW Research Center June 2020 survey reported 25% of Americans believed that the COVID-19 pandemic was definitely or probably "intentionally planned by powerful people"

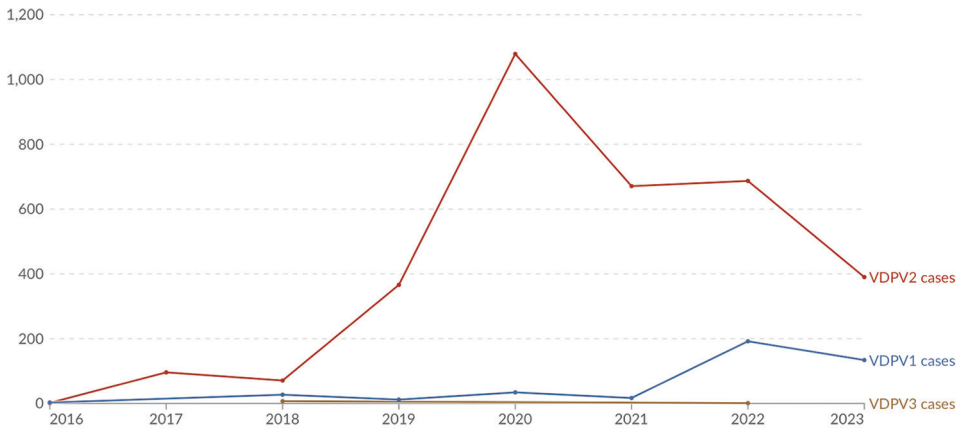

Figure 34. Vaccine-induced polio cases. Image obtained from Our World in Data.
Source: https://ourworldindata.org/grapher/cases-of-paralytic-polio-from-vaccine-derived-viruses-by-strain.

(ii) A "deep state" of America's elite is plotting to undermine the president, and Dr. Anthony Fauci, the face of the US coronavirus pandemic response, is a secret member working with Hillary Clinton
(iii) Greta Thunberg created the virus to help with climate change
(iv) Hand sanitizer companies created it
(v) Disney + released COVID for its launch
(vi) Netflix released it to increase viewers for its new series
(vii) According to 2020 PEW research, 23% of Americans believed that it was developed intentionally, with only 6% believing it was an accident
(viii) A United Kingdom astrobiologist claimed it piggybacked across the universe on a meteorite
(ix) Genetically modified crops caused genetic pollution that allowed viruses to proliferate due to the environmental "imbalance"
(x) Food from US Chinese restaurants caused the virus to spread
(xi) The Pope said that it is a punishment for mishandling climate change
(xii) President Donald Trump is waging a secret war against an elite of devil-worshipping pedophiles
(xiii) Bill Gates created the virus, patented it, and would use vaccines to force vaccinating everyone to control them through an injected microchip or quantum-dot spy software. 5G networks were burned down in response. 25% of Americans and 44% of Republicans in a May 2020 YouGov poll believed this.

Some of the misinformation addressed how to avoid or treat COVID-19.

(i) Turkmenistan banned the word coronavirus, hoping that would keep it away
(ii) You do not have to avoid or treat it because it is a hoax, no worse than the flu
(iii) Vodka will cure COVID-19, according to the Belarusian President
(iv) Eat garlic
(v) Consume bleach, which led to COVID-19 humor
(vi) Avoid spicy foods
(vii) Take cocaine
(viii) Russia released lions to enforce social distancing
(ix) Wearing masks can cause carbon dioxide poisoning
(x) The Philippines' President said to use clean masks with gasoline or diesel fuel.
(xi) Hydroxychloroquine is great. A total of 26% of Americans supported President Trump's medically dangerous claims
(xii) Drink cow urine
(xiii) Spread the body with cow dung as shown, which appeared in many publications. This sadly led to a fatal bacterial infection.

8.4. Charming consequences

There were also some charming consequences from the pandemic. A COVID Park opened in Vietnam's Tuyen Lam Lake National Tourist Complex. Figure 35 is a view of part of the park that appears on many websites.

Other examples include hoarding of toilet paper, changes in referees' behaviors without crowd pressure, causing the home team advantage to drop, and a measurable cooling of the moon due to decreased pollution. In addition, there were studies on changes in many parts of our lives, such as the yak economy in Sikkim, India, the mango economy in Ghana, and the livelihood of female waste pickers.

Researchers documented shifts in tourism patterns in Kyoto, increased households, and changes in US home gardening and sportfishing. Other findings highlighted the impact of fishing in Moorea, French Polynesia, recreational hunting in Europe, German cross-country skiing, the seafood supply in the Galapagos, wildlife diversity, and wildlife behavioral changes, such as those in mountain lions, squirrels, and bowing deer. The pandemic also influenced bird song loudness, fish biodiversity, whale migration, and even the resurgence of bloodsucking sea lampreys. Changes were also observed in the operation of sex workers (poke for a stroke), performance of soccer

Figure 35. Vietnam's COVID Park
Source: COVID Park (https://www.msn.com/en-us/travel/article/traveler-stumbles-on-bizarre-covid-19-theme-park-it-all-feels-pretty-dystopian/ar-AA1vFPqo).

players and referees, the Paris and Tokyo Olympics, and patterns of piracy.

9. Conclusion

Once it was confirmed that the primary infection transmission route is through aerosol spray, it was clear that eradicating COVID-19 would require drastic changes in behavior, or 8 million Americans and 115 million of the world's population would have died from COVID-19 in 2020. All countries' COVID-19 responses were led by their leaders, not their health departments. Leaders have great powers of persuasion, particularly in a crisis. Thus, each country's leader largely determined his/her country's fate.

The only 2020 measures against COVID were the mandated NPIs, which were face masks, social distancing, school closures, and lockdowns/stay-in-place orders. Others included border closures, hand washing, disinfection, wearing glasses/goggles, clean air, testing, and contact tracing. All of them reduced COVID-19 cases and deaths. In fact, just face masks, avoiding crowded places, the use of the iodine-based nasal spray, washing one's hands or using Purell, and rapid antigen tests can keep one safe. Hence, why were so many people in the US affected by COVID-19? Part of the reason was that Republican states implemented fewer of the mandated NPIs and were less compliant with them. Furthermore, the tradeoff between safety and quality of life often tilted in favor of quality of life, such as eating at indoor restaurants.

Unfortunately, all of these measures had negative consequences. Isolation was perhaps the most pernicious and contributed to increased mental illnesses, DoD, increased deaths from postponed medical procedures, and reduced children's math and reading skills. All are frightening long-term effects for our future health.

When considering how to prepare for the next pandemic, we must recognize that there are no easy answers. As H. L. Mencken said, "For every complex problem there is an answer that is clear, simple and wrong." Each of our choices, such as whether to close the schools or not, is an ethical dilemma. Since 1980, Michael Sandel has taught Harvard's most popular course, "Justice." Competing student teams address justice's ethical dilemmas such as affirmative action, income distribution, same-sex marriage, and the role of markets in a classroom debate. In all cases, it is clear that there are no simple answers to complex problems, which is also the case for COVID NPIs.

Without NPIs, deaths in the US would have risen from 1 million to 8 million. The ethical dilemma is how many lives would a nation be willing to sacrifice to avoid the negative consequences of lockdowns and school closures? In the US, is it none, 50,000, 100,000, or 1,000,000? What if one of the deaths were a family member? One's political leanings likely influence one's answer.

The right question, of course, is not what the balance should be but rather how to avoid the need for it. There is an initiative called the 100-day vaccine development. While achieving 1rapid vaccine development and deployment within 100 days is complex, as reported in a separate paper (Martin, 2024), its success could defeat the virus and reduce the need for oppressive NPIs. Without the 100-day vaccine or new breakthroughs, these stringent, mandated measures will once again be necessary in the next inevitable pandemic.

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