RESEARCH REPORT

The Impact and Prevention of Airborne Diseases

An Updated Review of Scientific Evidence

The RAD Project

Contents

Executive Summary

Airborne illnesses have become far more prevalent in recent years. Just recently (in January, 2026), flu-like illnesses in the United States hit a 25-year high, with medical facilities around the world starting to experience significant strain. In 2024, pneumonia was the sixth largest cause of death in Canada, and bacterial pneumonia hit a 26-year record high in Sweden. In 2023, the number of global tuberculosis cases hit a 28-year record high, and the number of US cases hit a 11-year record high, ending a multi-decade downtrend. In 2025, cases of measles in the US hit a 33-year record high.

This report provides a concise, data-driven discussion of airborne diseases and the tools we can use to reduce them. Airborne infections (like influenza, COVID-19, RSV, bacterial pneumonia, tuberculosis, and measles) put a strain on medical facilities, reduce economic growth, increase school absences, and lead to worse health outcomes even in healthy people. They also make it harder for vulnerable individuals to access essential indoor spaces, like hospitals and public transit.

Reducing these illnesses is a benefit to society at large. Thankfully, we have the knowledge and technology to do so, and the economic rewards are considerable.

KEY INSIGHTS

1. Respiratory infections are far more common and damaging than many realize, and they are primarily airborne. Airborne transmission is a risk whether "aerosol-generating procedures" (AGPs) are taking place or not.

2. Reducing airborne disease is feasible and has large economic benefits. Improving natural ventilation is one of the most cost-effective approaches we have.

3. N95 respirators are a powerful tool that drastically lowers the chance of catching and spreading airborne infections. We can greatly reduce airborne disease by wearing them in high-risk settings (e.g. in medical facilities, on public transit, and during illness waves).

4. Vaccination alone is insufficient for controlling the spread of airborne infections. Unlike respirators, vaccines struggle against recent strains. It's common for vaccinated people to catch and spread airborne illnesses.

5. Some microorganisms benefit the immune system, but this idea applies to environmental bacteria, not infectious pathogens like influenza, SARS-CoV-2 (COVID-19), and RSV. In fact, even initially mild cases can cause long-term health problems.

What are the benefits of reducing airborne disease?

Airborne diseases put a strain on medical facilities, increase the prevalence of pneumonia, reduce economic growth, increase school absences, and lead to worse health outcomes even in healthy people. They also make it harder for vulnerable individuals to access essential indoor spaces, like hospitals and schools. Reducing these diseases is a benefit to society at large.

Reducing Strain on Medical Systems

Medical staff members frequently catch airborne illnesses while at work, increasing the number of staff absences. Large rises in airborne illnesses put a strain on medical facilities, leading to bed shortages and diagnostic errors.

> "We followed 5,871 HCP (healthcare personnel) from November 2023 to May 2024… Overall, SARS-CoV-2 (COVID) infection and influenza accounted for 76.5% and 9.7% of total days missed, respectively." (source)
>
> "An unusually virulent respiratory illness season in northeastern Ontario [in 2026] is pushing hospitals to their limits like never before, and forcing them to put patients in more unconventional spaces…" (source)
>
> "It is common for the surge of patients with respiratory illnesses to cause hospital bed shortages each winter... This often happens when healthcare facilities are most overcrowded and in need of more staffing." (source)
>
> "During pandemics, the overwhelming strain on healthcare staff and the system itself has been identified as contributing factors [to diagnostic errors]..." (source)

Since COVID-19 emerged, illness-related absences among medical staff have become significantly elevated. When we examine the trend visually, we can clearly see that we are in a new regime.

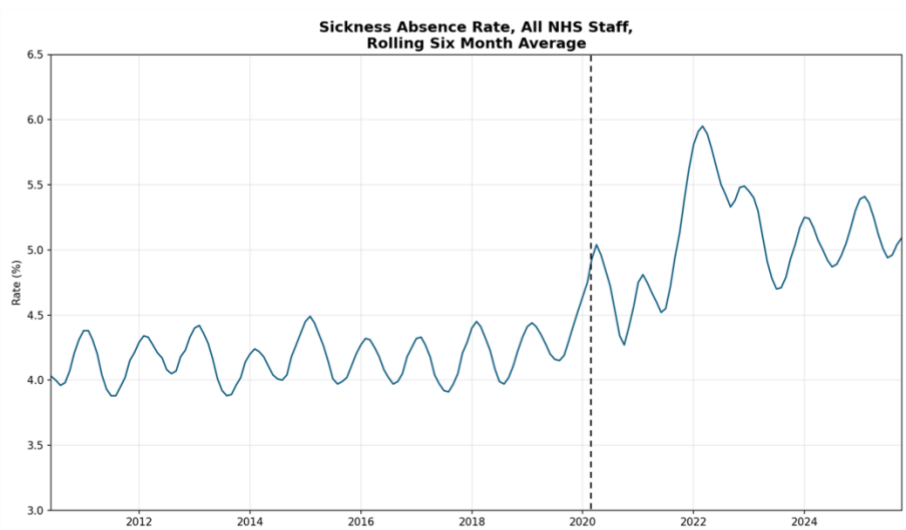

Figure 1 – Average Rate of Sickness Absences Among NHS Staff - based on NHS data (link) and chart provided by 1goodtern (link)

Every year, thousands of hospital patients become ill with airborne infections while seeking medical care. Hospital-acquired infections (HAIs), aka "nosocomial infections," are a major issue for patients. In Canada, between 20% and 30% of COVID-19 hospitalizations were hospital-acquired infections, based on data from 2023 to 2025.

> "We estimate there are approximately 18,955 pediatric and adult cases of nosocomial (hospital-acquired) respiratory viral infections in US acute care hospitals each year." (source)
>
> "Health care–acquired viral respiratory infections are common and cause increased patient morbidity and mortality... Transmission of respiratory viruses occurs in a variety of health care settings, resulting in increased patient morbidity and health care costs." (source)
>
> "We estimate that between June 2020 and March 2021 between 95,000 and 167,000 inpatients acquired SARS-CoV-2 (COVID) in [UK] hospitals." (source)

Reducing Prevalence of Pneumonia

Pneumonia is most commonly caused by airborne viruses and bacteria, including influenza, RSV, COVID-19, rhinoviruses, and Streptococcus pneumoniae. In 2024, this condition was the sixth largest cause of death in Canada. Pneumonia is also a leading cause of child mortality.

> "Many pathogens cause community-acquired pneumonia… Common bacterial pathogens…Streptococcus pneumoniae... Among viruses, rhinovirus, influenza, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2 [COVID]), and other respiratory viruses (parainfluenza, respiratory syncytial virus [RSV], human metapneumovirus, etc.) have become increasingly detected as pathogens." (source)
>
> "S. pneumoniae (Streptococcus pneumoniae) is spread through airborne droplets, and it is estimated to cause about four million illnesses within the United States (US) and about 450,000 hospitalizations per year." (source)
>
> "The long-range airborne, fomite [surface] and close contact routes contribute to 54.3%, 4.2% and 44.5% of influenza A infections, respectively... Mask wearing is much more useful than hand washing for control of influenza A in the tested office setting." (source)
>
> "The majority of [SARS-CoV-2, aka COVID] virus was contained within particles <5 µm in size… These findings indicate that SARS-CoV-2 is an airborne virus" (source)
>
> "Airborne particles containing influenza and RSV RNA were detected throughout a health care facility" (source)

Reducing Economic Losses from Sickness

Airborne illnesses also place a significant burden on the economy.

> "The estimated average annual total economic burden of influenza to the [US] healthcare system and society was $11.2 billion ($6.3-$25.3 billion). Direct medical costs were estimated to be $3.2 billion ($1.5-$11.7 billion) and indirect costs $8.0 billion ($4.8-$13.6 billion)." (source)

> "Long COVID… economic impacts… are estimated at an average annual burden of $1 trillion globally and $9000 per patient in the USA, with some individuals covering substantial out-of-pocket expenses. Annual lost earnings in the USA alone are estimated at approximately $170 billion." (source)
>
> "In this nationally representative cohort study of approximately 158.4 million workers, rates of health-related work absences remained elevated after the pandemic... COVID-19 may have created a new year-round baseline for work absences that is similar to influenza season conditions before the pandemic" (source)
>
> "Among 265 million US adults aged ≥18 years in 2023, 6.5 million medically attended episodes of RSV-LRTD were projected to occur... Direct costs ($15.2 billion) and indirect costs ($9.7 billion) were projected to total $25.0 billion." (source)
>
> "Each year in the UK there are approximately 3.6 million cases of RSV in adults. The total economic cost is estimated to be around £319m annually (in 2023 price terms), equivalent to a mean cost per adult with RSV of £87.51 per case." (source)
>
> "...without the above-average number of sick days [in 2023], Germany's economy would have expanded by 0.5% in 2023 rather than declining by 0.3%. In short, this means Germany's high rate of sickness cost its economy about €26 billion last year." (source)

Reducing School Absences and Closures

These infections lead to more school absences and closures.

> "Systematic Review on School Absenteeism for Influenza Surveillance… Influenza causes considerable disease burden each year, particularly in children… We found a median correlation of 0.4 (IQR 0.2–0.6) between K-12 student absenteeism and the number of community-level cases of influenza or ILI." (source)
>
> "The increases seen in the latter weeks of term [08 September to 20 December 2025] were mainly driven by illness-related absence… This increase in absence is equivalent to approximately 500,000 less days in school compared to the previous autumn term." (source)
>
> "At least 26 of Kentucky's 171 school systems have closed or gone remote because of widespread illness so far in November [of 2022]" (source)
>
> "during the 2012-2013 through 2014-2015 influenza seasons… Among 1027 children, 2,295 days of school were missed due to medically attended ARIs (acute respiratory illnesses)… viral illness accounted for about 75% missed school days [due to ARIs]." (source)

Reducing Damage to Individuals' Health

We now know that initially mild infections can do meaningful damage to healthy people. For example, initially mild COVID-19 cases can result in persistent, long-term symptoms ("long COVID") such as cognitive impairment, lung issues, and immune system issues.

> "In this population of healthy young adult US Marines with mostly either asymptomatic or mild acute COVID-19, one fourth reported… long-term sequelae of infection… we identified cardiopulmonary (heart and lung) symptoms as some of the most prevalent." (source)
>
> "The [mild to moderate] COVID-19 group demonstrated significantly lower cognitive function and lower functional connectivity in multiple brain regions." (source)
>
> "Non-hospitalized COVID-19 patients had a threefold higher risk of incident pulmonary conditions compared to non-COVID controls" (source)
>
> "The memory T cells of people who experience mild COVID-19 symptoms show the molecular signs of exhaustion and therefore could have a reduced ability to fight reinfection." (source, source)

Many viral infections, like COVID-19 and influenza, significantly increase the risk of longer-term health problems, such as congenital heart disease (CHD), diabetes, and cancer.

> "SARS-CoV-2 (COVID) infection was associated with an increased risk of CHD (RR, 1.74) and stroke (RR, 1.69)... influenza infection was associated with an elevated risk of acute myocardial infarction (pooled incidence rate ratio, 4.01) and stroke during the first 1 month (incidence rate ratio, 5.01)." (source)
>
> "5,084,889 US adults… SARS-CoV-2 (COVID) infection independently associated with increased 5-year risk of prediabetes (HR 1.23; 95% CI 1.21–1.25) and type 2 diabetes (HR 1.40; 95% CI 1.37–1.43)… Rigorous propensity matching controlled for demographics, comorbidities, and metabolic parameters" (source)
>
> "Among 2,044,421 individuals… over a median follow-up of 874 days. Compared with the SARS-CoV-2-negative group, the risk of diabetes was higher among infected individuals (HR 1.18; 95% CI: 1.15–1.22; $p < 0.0001$)" (source)
>
> "…data from national health registries for the entire Norwegian population under the age of 30 years for the years 2006–2014 (2.5 million individuals)… In the subgroup with laboratory-confirmed influenza A (H1N1), influenza was associated with a twofold higher risk of subsequent type 1 diabetes before age 30 years (adjusted HR: 2.26, 95% CI 1.51, 3.38)" (source)
>
> "…adjusted analysis showed that individuals had a 1.3-fold (95% confidence interval: 1.15–1.46) higher risk of developing type 1 diabetes in the first 180 days after influenza diagnosis than that at other times" (source)
>
> "We performed the Mendelian randomization (MR) to investigate the causal associations… Together, our study indicated that COVID-19 had causal effects on cancer risk." (source)
>
> "Analyses of cancer survivors from the UK Biobank (all cancers) and Flatiron Health (breast cancer) databases reveal that SARS-CoV-2 (COVID) infection substantially increases the risk of cancer-related mortality and lung metastasis compared with uninfected cancer survivors." (source)
>
> "An estimated 15 percent of all human cancers worldwide may be attributed to viruses." (source)

Increasing the Freedom of Vulnerable Individuals

Many individuals are especially vulnerable to infections, such as cancer patients, the disabled, the elderly, infants, and the immunocompromised. Essential indoor public spaces (hospitals, supermarkets, public transit, schools, etc.) should be accessible to everyone, but they become more dangerous for vulnerable individuals when airborne infections are more prevalent in the community.

Increasing accessibility helps the vulnerable participate in society and avoid isolation. Being socially isolated is strongly associated with negative physiological health outcomes. Additionally, taking care of the vulnerable is a timeless moral principle, and it's a requirement of medical ethics codes.

> "Social Relationships and Mortality Risk: A Meta-analytic Review... The influence of social relationships on risk for mortality is comparable with well-established risk factors for mortality... The magnitude of this effect is comparable with quitting smoking and it exceeds many well-known risk factors such as obesity and physical inactivity." (source)
>
> "Social isolation and loneliness are also associated with increased morbidity and dysregulation of various biomarkers of health, such as inflammation." (source)
>
> "...then Anu and Bel called by name me, Hammurabi... to bring about the rule of righteousness in the land... so that the strong should not harm the weak" [The Code of Hammurabi] (source)
>
> "Give justice to the weak and the fatherless; maintain the right of the afflicted and the destitute." [Psalm 82:3 ESV] (source)
>
> "A physician shall support access to medical care for all people." (source)
>
> "...improve health outcomes and access to care, reduce health inequities and disparities in care... Take all reasonable steps to prevent or minimize harm to the patient" (source)

What about natural immunity?

While some microorganisms can be good for our immune system, this idea doesn't apply to infections like COVID-19, influenza, and RSV. These illnesses cause meaningful harm, even in initially mild cases.

Decades ago, scientists thought that exposure to influenza and other infectious pathogens was key for the development of our immune system. This theory arose because researchers noticed a correlation – allergies were becoming more common during a time when hygiene was improving and childhood infections were declining. Thus, the Hygiene Hypothesis was born, arguing that hygiene (and a lack of childhood infections) was to blame for the rise in immune system issues.

Some 14 years later, scientists realized that another factor offered a better explanation – allergic diseases were rising because children were spending most of their time indoors and getting less exposure to beneficial microorganisms that we've co-evolved with for our entire human history. These organisms, known as our "Old Friends," include harmless bacteria and other microbes that live outdoors. They also include bacteria that children are exposed to during vaginal births, which were becoming less common due to the rise in C-sections at that time.

In contrast to our Old Friends, influenza and other infectious pathogens have only been with us for 3 to 4% of our evolution, after humans began to mostly live in crowded cities with large networks of social contacts. Those newer infections, known as "crowd infections," are not essential stimuli for our immune systems to develop. Instead, they damage the body and increase the risk of further health complications. Crowd infections include influenza, COVID-19, RSV, measles, tuberculosis, and bacterial pneumonia.

The Old Friends Hypothesis is now recognized as being more consistent with available evidence than the previous theory, the Hygiene Hypothesis.

> "Today, epidemiological, experimental, and molecular evidence support a different hypothesis: Early exposure to a diverse range of 'friendly' microbes [Old Friends]—not infectious pathogens—is necessary to train the human immune system to react appropriately to stimuli" (source)
>
> "Crowd infections need large populations and networks of social contacts… Such populations did not exist until well after 10 000 BCE, when agriculture and permanent settlements initiated the transition to larger population densities. Thus humans did not co-evolve with the crowd diseases, and the crowd diseases did not need to be tolerated (they killed the host or generated solid immunity) so, as anticipated, they play little role in setting up immunoregulatory pathways" (source)
>
> "The Old Friends (OF) Mechanism was proposed by Rook in 2003 and argues that the vital microbial exposures are not colds, measles and other childhood infections (the crowd infections), but rather microbes already present during primate evolution and in hunter-gatherer times when the human immune system was evolving [old friends]…. Whereas the hygiene hypothesis implicated childhood virus infections as the vital exposures, from an evolutionary point of view this was never likely." (source)

Once COVID-19 emerged, the Hygiene Hypothesis inspired a popular misconception called "immunity debt." The idea was that pandemic restrictions caused immune systems to weaken because they were temporarily exposed to fewer infections. However, pandemic restrictions in most of the world lasted for around a year, and the idea that immune systems would materially weaken in such a short time period is an unfounded claim that lacks empirical support and mechanistic explanations.

> "'Immunity debt' is a concept that arose during the COVID-19 pandemic… Currently, there is no scientific evidence that public health interventions had any long-term impact on the strength or capacity of children's immune systems." - The American Association of Immunologists (source)
>
> "In children and in young, healthy people, there is absolutely no mechanism by which your immunity weakens on its own" - Colin Furness, an infection control epidemiologist (source)
>
> "Many infants and toddlers admitted to hospital with rare infections since 2022 weren't yet born when pandemic restrictions were in place, and they therefore couldn't be experiencing immunity debt. They were, however, likely exposed to SARS-CoV-2 (COVID-19)" (source)
>
> "The 'immunity debt' hypothesis suggests the immune system is like a muscle requiring near-constant exposure to infectious agents to keep it functioning… Though this idea has gained traction, there's no immunological evidence to support it. It's not true to say we require a constant background of infection for our immune system to work." - Dr. Sheena Cruickshank,

> Deputy Lead of the Eco-Immunology and Context-Specific Immunology Branch of the Lydia Becker Institute of Immunology and Inflammation (source)

For children born in 2020, lockdowns may have delayed their initial exposure to infections. However, this delayed initial exposure doesn't explain immune system issues observed in children who were born in subsequent or prior years. It also doesn't explain immune system issues observed many years later, when children no longer lacked their initial exposures. Overall, the rise in illnesses among children broadly cannot be explained solely by those who were born just before 2020 lockdowns.

In general, we know that childhood infections aren't protective; they actually cause considerable harm, increasing the risk of developing asthma and other conditions.

> "Not being infected with RSV during infancy was associated with a 26% lower risk of 5-year current asthma than being infected with RSV during infancy. The estimated proportion of 5-year current asthma cases that could be prevented by avoiding RSV infection during infancy was 15%." (source)
>
> "Early-life infection burden may continue throughout childhood and is associated with later antibiotic treatments… Children with a high vs low burden of diary-registered infections between birth and 3 years had an increased risk of later moderate to severe infections (AIRR, 2.39; 95% CI, 1.52-3.89) and systemic antibiotic treatments" (source)
>
> "Influenza poses a significant disease burden on children worldwide, with high rates of hospitalization and substantial morbidity and mortality." (source)
>
> "Children and adolescents with prior SARS-CoV-2 (COVID) infection are at a statistically significant increased risk of various cardiovascular outcomes, including hypertension, ventricular arrhythmias, myocarditis, heart failure, cardiomyopathy, cardiac arrest, thromboembolism, chest pain, and palpitations, compared to uninfected controls." (source)
>
> "…long-term effects of COVID-19 in children and young people: 7.2% of CYP (children and young people) consistently fulfil the PCC (long COVID) definition at 3-, 6-, 12- and 24-months." (source)

In contrast, vaccines provide immunity without damaging the body with an infection. Whether immunity is obtained via vaccines or infections, it does wane over time and as pathogens evolve. Thankfully, it can be safely maintained via repeated vaccinations; conversely, repeated natural infections increase mortality risk over time and subject the body to more damage.

> "Vaccines contain antigens that stimulate the immune system to produce an immune response that is often similar to that produced by the natural infection. With vaccination, however, the recipient is not subjected to the disease and its potential complications." (source)
>
> "Previous infection comes with considerable risks of morbidity, mortality, and transmission… as a surrogate for natural infection, vaccination remains the safest approach to protection." (source)
>
> "For the vast majority of people, [the claim that it is better to acquire immunity through infection] is also patently false, since the risks of serious illness and dying from natural infection are considerably higher than those of vaccination." (source)

> "Adverse effects have been minimal for COVID-19 vaccines, indicating a nominal level of risk exposure. SARS-CoV-2 (COVID-19) exposure, meanwhile, carries significant and well-documented dangers… the vaccine is far safer than natural infection." (source)
>
> "Reinfection (COVID-19) patients were at a significantly higher risk of all-cause mortality within 30 days (aHR = 4.29, 95% CI: 3.00–6.12, p < 0.001) comparing with non-reinfection patients" (source)
>
> "(COVID-19) reinfection further increases risks of death, hospitalization and sequelae in multiple organ systems in the acute and postacute phase" (source)
>
> "We identified 407,300 eligible children and adolescents with a first (COVID-19) infection episode and 58,417 with a second infection episode from Jan 1, 2022, to Oct 13, 2023… Reinfection was associated with a significantly increased risk of an overall PASC (Long COVID) diagnosis (RR 2·08 [1·68–2·59]) and a range of symptoms and conditions potentially related to PASC (RR range 1·15–3·60), including myocarditis" (source)
>
> "Older adults with multiple infection episodes, irrespective of type, pathogens, and distinct infection pattern, had greater risk of all-cause mortality compared with those with infrequent infections" (source)

Though rarely acknowledged, ample research indicates that infections can actually impair the immune system and increase the risk of secondary infections. See the studies below regarding measles and influenza.

> "Long-term measles-induced immunomodulation increases overall childhood infectious disease mortality... it was determined that it takes approximately 2-3 years post-measles infection for protective immune memory to be restored." (source)
>
> "measles infection can greatly diminish previously acquired immune memory, potentially leaving individuals at risk for infection by other pathogens. These adverse effects on the immune system were not seen in vaccinated children." (source)
>
> "Our findings indicate that influenza virus infection induces an immune-suppressive state – even in previously vaccinated and immune individuals – by directly attacking activated immune cells, thus leaving the patients vulnerable to severe disease and leading to vaccine failures during influenza seasons." (source)
>
> "There is impairment in the ability of human DCs (dendritic cells) infected with influenza viruses to prime T cells towards the Th1 phenotype required for effective antiviral adaptive immune responses." (source)

COVID-19 is particularly known for causing immune system issues. In fact, the Merck manual, a reference aid for doctors, notes that COVID-19 and HIV (the virus that causes AIDS) are two common causes of lymphocytopenia, an immune system disorder where the body lacks enough white blood cells to successfully fight future infections. Even mild cases can impair the immune system, as demonstrated by the studies below.

> "The memory T cells of people who experience mild COVID-19 symptoms show the molecular signs of exhaustion and therefore could have a reduced ability to fight reinfection." (source, source)
>
> "Immunological dysfunction persists for 8 months following initial mild-to-moderate SARS-CoV-2 infection" (source)
>
> "long-term immune monitoring… after a first mostly mild infection…we found a significant reduction of adaptive immune cells, including T cells and B cells, 10 months after COVID-19" (source)
>
> "we examine the function of classical CD14+ monocytes (white blood cells) in patients with mild and moderate COVID-19… in healthy individuals. Monocytes from COVID-19 patients display… a dysfunctional metabolic profile that distinguish them from healthy monocytes." (source)
>
> "We also found that previous SARS-CoV-2 infection resulted in decreased CD8+ T cell activation and expansion [after vaccination]… the apparent damage of the CD8+ T cell response by viral infection is cause for concern and may leave even vaccinated individuals with a previous infection at risk for subsequent infections." (source)
>
> "Our results suggest that a positive test for COVID-19 (*vs* a negative test) was associated with increased rates of diagnosis of various infections in the 12 months following an acute SARS-CoV-2 infection." (source)

Unsurprisingly, clinicians have noticed that illnesses have become far more common in the years since COVID-19 emerged and repeatedly infected most of the world.

> "It is noticeable that people have become more susceptible to infection since the coronavirus pandemic… We see more intensive care patients [with] every viral disease than before. That in itself is very unusual." (source)
>
> "Dr. Kashif Pirzada, an emergency physician and faculty member at the University of Toronto, says recent illness patterns are unlike anything he has seen in his 17 years practicing medicine… Pneumonia was 'surprisingly infecting a lot of children, which was not an issue before [the pandemic],' he says" (source)

How common is airborne transmission?

Airborne Spread is Most Common

A large body of scientific evidence demonstrates that respiratory infections are airborne, and that they primarily spread via biological aerosols (bioaerosols) – small exhaled droplets (0.3–100 microns in diameter) that linger in the air and get inhaled by others. Influenza, COVID-19, RSV, bacterial pneumonia, tuberculosis, and measles are all primarily spread via the airborne route.

> "The long-range airborne, fomite [surface] and close contact routes contribute to 54.3%, 4.2% and 44.5% of influenza A infections, respectively... Mask wearing is much more useful than hand washing for control of influenza A in the tested office setting." (source)
>
> "The majority of [SARS-CoV-2] virus was contained within particles <5 µm in size… These findings indicate that SARS-CoV-2 (COVID) is an airborne virus" (source)
>
> "Airborne particles containing influenza and RSV RNA were detected throughout a health care facility" (source)
>
> "M. pneumoniae is principally transmitted by aerosol inhalation of droplets" (source)
>
> "Pneumococcus (Streptococcus pneumoniae) resides primarily in the upper respiratory tract and is transmitted via aerosolized droplets." (source)
>
> "Tuberculosis is almost exclusively airborne" (source)
>
> "Measles is a highly contagious cause of febrile illness… It is transmitted primarily through respiratory droplets and small-particle aerosols and can remain viable in the air" (source)

Other Transmission Routes Are Poorly Supported

Contrary to popular opinion, there is very little empirical support for the idea that respiratory infections transmit via larger droplets. Unfortunately, many infection control guidelines and medical facilities overwhelmingly focus on this weakly-supported transmission route. This outdated focus, sometimes called the "droplet dogma," is a very real phenomenon, and it is undermining infection control efforts around the world.

> "There is no evidence to support the concept that most respiratory infections are associated with primarily large droplet transmission. In fact, small particle aerosols are the rule, rather than the exception, contrary to current guidelines." (source)
>
> "Given the lack of evidence for droplet and fomite transmission and the increasingly strong evidence for aerosols in transmitting numerous respiratory viruses, we must acknowledge that airborne transmission is much more prevalent than previously recognized." (source)
>
> "Mathematical modeling of exposure to respiratory pathogens supports that transmission is dominated by short-range aerosol inhalation at most distances within 2 m of the infectious person, and [large] droplets are only dominant when individuals are within 0.2 m when talking or 0.5 m when coughing" (source)

Another pervasive misconception is that surfaces (aka fomites) play a major role in the transmission of respiratory infections. This view has little empirical support.

> "Transmission route of rhinovirus [the cause of common colds]… A systematic review… We found low evidence that transmission via hands and fomite followed by self-inoculation is the dominant transmission route… This suggests that the major transmission route of RVs in many indoor settings is through the air" (source)

> "studies... suggest that the risk of SARS-CoV-2 (COVID) infection via the fomite transmission route is low, and generally less than 1 in 10,000" (source)
>
> "The risk associated with [influenza] transmission through contact with fomites is hypothetical, lacking solid quantitative evidence… We found that viable viruses were rarely transmitted to fingertips from the above fomites even when the viral loads in the viral fluid contaminating the fomites far exceeded that seen in real life… Consequently, we conclude that the probability of contact transmission of influenza via dried fomites is negligible or minimal" (source)
>
> "fomite transmission is an unlikely transmission route for enveloped respiratory viruses (note: this category includes influenza, RSV, measles, and coronaviruses [like COVID])" (source)
>
> "Transmission [of rhinoviruses] via fomites heavily used for 12 hr by eight donors was the only possible route of spread, and no transmissions occurred… These results suggest that contrary to current opinion, rhinovirus transmission, at least in adults, occurs chiefly by the aerosol route." (source)
>
> "… the [measles] virus does not survive long on fomites as it is quickly killed by heat and ultraviolet radiation." (source)
>
> "In a comprehensive investigation of shipboard [tuberculosis] transmission on a United States Navy vessel… Shared air fully accounted for the patterns of transmission seen… no evidence was found… of transmission through dust or fomites" (source)
>
> "M. pneumoniae is principally transmitted by aerosol inhalation of droplets" (source)
>
> "Pneumococcus (Streptococcus pneumoniae) resides primarily in the upper respiratory tract and is transmitted via aerosolized droplets." (source)

Airborne Spread Doesn't Require AGPs

Decades ago, the medical community believed that airborne transmission from patients was only a major risk during "aerosol generating procedures" (AGPs), such as intubation. This misconception remains a widely held belief. However, we now know that speaking and coughing can produce similar amounts of aerosols, if not more, than AGPs. Airborne transmission is a significant risk whether AGPs are taking place or not.

> "In fact, breathing, speaking, shouting, and singing all generate similar or higher levels of aerosols to many so-called AGMPs. Further, breathing is continuous and speaking occurs repeatedly over long periods, so the cumulative aerosol exposure is much higher from routine human emissions than from a single medical procedure." (source)
>
> "The term aerosol-generating procedure is a misnomer. It is not the procedure that increases risk but sustained proximity to the respiratory tract of a highly symptomatic patient." (source)
>
> "In fact, the aerosol emissions from tracheal intubation, high-flow nasal oxygen, and non-invasive ventilation are low, with similar sampled aerosol concentrations to tidal breathing and speaking." (source)

> "Just about every procedure we have classically characterized as aerosol-generating in fact generates little or no additional aerosols above and beyond the patient's baseline rate of generation." (source)
>
> "Fine aerosols produced by talking and singing contain more SARS-CoV-2 copies than coarse aerosols and may play a significant role in SARS-CoV-2 transmission. Exposure to fine aerosols, especially indoors, should be mitigated." (source)

Airborne Illnesses are Widespread & Surging

Airborne infections have become increasingly prevalent over the past several years. Just recently (in January, 2026), flu-like illnesses in the United States hit a 25-year high, with medical facilities around the world starting to experience significant strain. In 2024, pneumonia was the sixth largest cause of death in Canada, and bacterial pneumonia hit a 26-year record high in Sweden. In 2023, the number of global tuberculosis cases hit a 28-year record high, and the number of US cases hit a 11-year record high, ending a multi-decade downtrend. And in 2025, cases of measles in the US hit a 33-year record high.

Additionally, COVID-19 is still a widespread hazard. This is unsurprising given the fact that it is airborne, and the fact that airborne precautions (like wearing respirators) are not widely implemented. Official counts of COVID-19 cases are now severely underestimated, since labs and hospitals are no longer required to report COVID-19 cases to the government. The best available estimates for case counts come from wastewater data. Based on that data, since 2021 every major COVID-19 wave has had peak case counts that surpassed the peak case count in the initial 2020 worldwide wave.

Thankfully, we have powerful tools to combat these hazards: respiratory protection (N95-grade respirators), ventilation, air purification, and far-UVC devices.

How can we reduce airborne disease?

Airborne diseases primarily spread in indoor environments. When an infectious person exhales, they release aerosols - small infectious particles that linger in the air and infect others. To reduce the prevalence of airborne diseases, we need to clean the air and remove infectious aerosols from indoor environments.

Thankfully, we have four excellent tools that accomplish this. The problem is, we need to make more of an effort to consistently use them. These tools, known as airborne precautions, include:

- N95 respirators, which prevent infectious particles from being inhaled or exhaled into a room
- Ventilation, which replaces infectious air with cleaner air from outside
- Purification, which removes infectious particles from the air and traps them in filters
- Germicidal UV (far-UVC), which kills infectious microbes in the air

All of these tools are impactful, but combining them leads to an even better result.

N95 Respirators

N95 respirators are one of the most powerful tools we have to reduce airborne illnesses. These infections spread via small airborne particles called aerosols, and respirators effectively block aerosols from being inhaled. See the considerable evidence from experimental tests listed below.

> "The N95 respirator had the highest filtration efficiency (97.4% ± 0.3%), whereas the surgical mask could only prevent 18.4% of aerosol particles to penetrate inside the respirator… When the volunteers wore the N95 respirator for 3 days, the average filtration efficiency was 97.0%." (source)
>
> "N95 respirators… filtration efficiency… reaches approximately 99.5% or higher at about 0.75 micron. Tests with bacteria of size and shape similar to Mycobacterium tuberculosis also showed filtration efficiencies of 99.5% or higher." (source)
>
> "...efficacy of masks and respirators in blocking inhalation of influenza in aerosols…. A tightly sealed respirator blocked 99.8% of total virus and 99.6% of infectious virus" (source)
>
> "The filtration performance of the N95 respirator approached that of the two models of N99 over the range of particle sizes tested (~0.02 to 0.5 µm) (20 to 500 nanometers)... The N95 FFR demonstrated the lowest [breathing] resistance at each airflow while [the] N99 Model B possessed the highest." (source)
>
> "N95 respirators made by different companies were found to have different filtration efficiencies for the most penetrating particle size (0.1 to 0.3 micron), but all were at least 95% efficient at that size." (source)

In addition to experimental tests, we also have ample real-world evidence showing that N95 respirators significantly reduce the odds of catching airborne illnesses.

> "The usage of FFP2 (N95) masks reduced the incidence of viral respiratory infections from 20.7% to 2.0%." (source)
>
> "Meta-analysis indicated a protective effect of N95 respirators against COVID-19… the subgroup using N95 respirators, particularly medical staff, showed a significant protective [effect]." (source)
>
> "The odds of being SARS-CoV-2–positive were reduced by more than 40% in individuals using respirators irrespective of cumulative exposure" (source)
>
> "The adjusted odds of infection were lowest among persons who reported typically wearing an N95/KN95 respirator" (source)
>
> "Respirators compared to surgical masks may convey additional protection from SARS-CoV-2 for HCW with frequent exposure to COVID-19 patients" (source)
>
> "Whilst using FRSMs (surgical masks), HCWs working on red wards faced an approximately 31-fold increased risk of direct, ward-based infection. Conversely, after changing to FFP3 (N99) respirators, this risk was significantly reduced (52–100% protection)." (source)

Respirators offer another benefit; they prevent infectious air from entering the room. In the engineering world, hazards are mitigated with a variety of approaches known as "controls." The most effective type of control category is elimination, which involves trying to stop the hazard at its source (aka "source control"). Respirators provide source control by filtering exhalations, drastically reducing the volume of aerosols that a person exhales into the space. Unsurprisingly, infection risk drops considerably when people practice source control by wearing respirators. Surgical masks provide source control as well, but they are less effective since they tend to be loose fitting.

> "The hierarchy of controls has five levels of actions to reduce or remove hazards. The preferred order of action based on general effectiveness is: elimination, substitution…" (source)
>
> "Relative efficacy of masks and respirators as source control for viral aerosol shedding from people infected with SARS-CoV-2… A duckbill N95 reduced exhaled viral load by 98%, and significantly outperformed a KN95 as well as cloth and surgical masks" (source)
>
> "Respiratory source control using a surgical mask: An in vitro study… With cough, source control (mask or respirator on Source) was statistically superior to mask or unsealed respirator protection on the Receiver (Receiver protection) in all environments." (source)
>
> "Respiratory source control versus receiver protection: impact of facemask fit… Any mask applied to the source mannequin resulted in significant reductions in exposure." (source)
>
> "Efficacy of masks and face coverings in controlling outward aerosol particle emission from expiratory activities… These observations directly demonstrate that wearing of surgical masks or KN95 respirators, even without fit-testing, substantially reduce the number of particles emitted from breathing, talking, and coughing." (source)
>
> "We attribute the lower rate of healthcare-acquired infections in part to providing universal source control via masking, thereby mitigating the spread from asymptomatically infected or minimally symptomatic individuals." (source)

Since airborne infections spread exponentially, even small increases in masking can make a meaningful difference and reduce illness in the community. A single avoided infection can prevent a new group of infections from occurring.

> "Slight increases in mask adherence and/or efficacy above current levels would reduce the effective reproductive number (R_e) substantially below 1… [this] results in a significant reduction in transmission with widespread implementation… particularly if implemented comprehensively in potential super-spreader environments." (source)
>
> "We determine the probable impact of wearing face masks on trains over a seven-day simulation horizon, showing substantial and statistically significant reductions in new cases when passenger mask wearing proportions are greater than 80%. The higher the level of mask coverage, the greater the reduction in the number of new infections. Also, the higher levels of mask coverage result in an earlier reduction in disease spread risk." (source)

This is particularly important for influenza and SARS viruses (like COVID-19), since they can transmit via "superspreader" events, where a small number of infected people spread the pathogen to a large group of people.

> "indoor activities... have been characterized as potential superspreading events, and such events are the major drivers of the COVID-19 pandemic" (source)
>
> "based on data from 4,519 COVID-19 cases across eight regions in China… super-spreaders serve as critical drivers of epidemic spread. We found that 1.35 % of cases identified as super-spreaders directly responsible for 40.09 % of secondary cases." (source)
>
> "Superspreading, where a small proportion of individuals infect the majority of secondary infections, is a common feature of disease spread caused by individual variation [heterogeneity] in transmissibility" (source)
>
> "Controlled human influenza infection reveals heterogeneous expulsion of infectious virus into air… The observed heterogeneity among participants in symptoms, viral load dynamics, viral spatial distributions and infectious respiratory particle production suggest features of human influenza that may contribute to superspreading dynamics" (source)
>
> "Evaluating modes of influenza transmission… we previously observed substantial heterogeneity in viral aerosol shedding in studies of community-acquired influenza and SARS-CoV-2 (COVID) infections. Recent human challenge studies have reported similar variability." (source)

One advantage of respirators is that they reduce infection risk at close distances. Even when a sick person is very close to you, they are dramatically less likely to infect you if they are wearing an N95-grade respirator. This is important because a sizable fraction of airborne transmission (~40%) occurs at short range.

Keep in mind that respirators significantly outperform other types of face coverings, such as surgical masks.

> "The N95 respirator had the highest filtration efficiency (97.4% ± 0.3%), whereas the surgical mask could only prevent 18.4% of aerosol particles to penetrate inside the respirator… When the volunteers wore the N95 respirator for 3 days, the average filtration efficiency was 97.0%." (source)
>
> "The total particle penetration into the SM (surgical mask) was about 10-fold greater than the penetration into the FFR (respirator), which means that the particle count inside the N95 FFR was an order of magnitude lower than that inside the SM." (source)
>
> "The filtration efficiency at the most penetrating particle size of 0.3 µm on average ranged from 83–99% for N95 and KN95 respirators, 42–88% for surgical masks, 16–23% for cloth masks, and 9% for bandana." (source)
>
> "Loose-fitting surgical masks with straps allow profound inward leakage through gaps along the mask edges. Research has shown that surgical masks allow 8–12 times more penetration than N95 FFRs, with 86% of this penetration caused by lack of faceseal." (source)

Ventilation

Ventilation is another high-impact tool that significantly reduces infection risk. Increasing natural ventilation and mechanical ventilation can make a big difference; see the following studies.

> "Simple modifications to existing hospital infrastructure considerably increased natural ventilation, and greatly reduced modelled TB transmission risk at little cost." (source)
>
> "Opening windows and doors maximises natural ventilation so that the risk of airborne contagion is much lower than with costly, maintenance-requiring mechanical ventilation systems. Old-fashioned clinical areas with high ceilings and large windows provide greatest protection." (source)
>
> "The Influence of Ventilation Measures on the Airborne Risk of Infection in Schools: A Scoping Review… ventilation in many schools is not adequate… Ventilation is an important measure for reducing the risk of airborne infections in schools." (source)
>
> "Four studies were performed in elementary grade classrooms, and one study assessed ventilation and absence in day care centers…Overall, the available research indicates that increased ventilation rates in classrooms are associated with reduced student absence." (source)
>
> "We investigated… 28 schools in three school districts… increasing classroom VRs (ventilation rates) from the California average (4 l/s-person) to the State standard would decrease IA (illness absence) by 3.4%, increase attendance-linked funding to schools by $33 million annually… would substantially decrease illness absence and produce economic benefits." (source)

During colder time periods, having adequate mechanical ventilation is especially critical; building occupants typically avoid opening windows when outdoor air is frigid. This reduces natural ventilation and makes occupants more reliant on other sources of clean airflow.

In real-world settings, many indoor spaces don't deliver adequate ventilation rates, falling short of industry standards. Additionally, it's common for medical facilities to prevent patients from opening windows, and to have windows that are inoperable or sealed shut. To address these issues, facilities should routinely test their ventilation systems, and they should fix inoperable windows and modify existing windows so that they can open.

> "Out of 11 classrooms tested with the CO_2 tracer method, only three met ASHRAE and one met ACGIH targets (ventilation standards)." (source)
>
> "When compared to Standard 170… 39% [of clinic rooms] did not meet the requirement for treatment rooms, 83% did not meet the requirement for aerosol-generating procedures, and 88% did not meet the requirement for procedure rooms or minor surgical procedures." (source)
>
> "No hospital had tested routinely the efficacy of the negative pressure ventilation." (source)
>
> "Patients are generally not permitted to operate the system unless instructed to do so (this includes opening windows)." (source)
>
> "X-ray department waiting room: This busy corridor has doors opening along one side to the X-ray rooms and had 27 unopenable windows to the outside on the opposite wall, where patients wait on benches…Respiratory medicine out-patients & TB clinic waiting room... the three remaining walls had a row of high unopenable windows." (source)

Air Purifiers

Additionally, air purifiers with HEPA filters significantly reduce infectious particles in indoor spaces.

> "Portable HEPA Purifiers to Eliminate Airborne SARS-CoV-2 (COVID): A Systematic Review… In all studies, portable HEPA purifiers were able to significantly reduce airborne SARS-CoV-2-surrogate particles… Experimental studies provide evidence for portable HEPA purifiers' potential to eliminate airborne SARS-CoV-2 and augment primary decontamination strategies such as ventilation." (source)
>
> "The study involved 30 schools… underlying illness absence rate was reduced by more than 20% in those schools with HEPA air filters in place" (source)
>
> "At The Hayling College, headteacher Martyn Reah introduced high-efficiency particulate air (HEPA) filtration units into classrooms two years ago… illness-related absence fell from 4.3% to 3.4%, a reduction of around 21%. For a school of Hayling's size, this equates to more than 4,500 additional pupil-days in school every autumn term. And the cost? Around 5 pence per pupil per day" (source)
>
> "The classroom equipped with HEPA filters saw a 47% reduction in absences compared with those without filters." (source)
>
> "Air purification reduced sickness by 18% in a study conducted in [four different] Helsinki daycare centers" (source)
>
> "With air cleaners, mean particle concentration decreased by 77% (95% credible interval 63%–86%)... Absences related to respiratory infections were 22 without vs 13 with air cleaners. Bayesian modeling suggested a reduced risk of infection, with a posterior probability of 91% and a relative risk of 0.73 (95% credible interval 0.44–1.18)." (source)
>
> "In times when classes were conducted with windows and door closed, the aerosol concentration was reduced by more than 90% within less than 30 min when running the purifiers (air exchange rate 5.5 h^{-1})." (source)

Air purifiers excel at cleaning the air, but they can be quite loud, and teachers often turn them off as a result. The solution to this is to use air purifiers that have PC fans, which supply ample airflow at a fraction of the volume level.

> "Nearly seven-in-ten (69%) of K-12 teachers in the survey turn off or turn down their in-room portable HEPA filters due to the noise they produce." (source)
>
> "Clean Air Kits produce 5-10x less noise than HEPA purifiers at max capacity. ... Speed controls defeat the efficacy of most HEPAs -- people turn them down to quiet where air cleaning slows. We have just one speed: silent full blast!" (source)

Far-UVC Devices

Far-UVC devices are also excellent at cleaning indoor air and reducing infection risk, especially when they are installed in the ceiling.

> "Using four 222-nm fixtures installed in the ceiling, and staying well within current recommended regulatory limits, far-UVC reduced airborne infectious MNV (murine norovirus) by 99.8% (95% CI: 98.2–99.9%)." (source)
>
> "At a room ventilation rate of 3 air-changes-per-hour (ACH), with 5 filtered-sources the steady-state pathogen load was reduced by 98.4% providing an additional 184 equivalent air changes (eACH)." (source)
>
> "Low doses of 1.7 and 1.2 mJ/cm2 inactivated 99.9% of aerosolized coronavirus 229E and OC43, respectively. As all human coronaviruses have similar genomic sizes, far-UVC light would be expected to show similar inactivation efficiency against other human coronaviruses including SARS-CoV-2." (source)

How to Implement These Tools

Basics – Main Idea of ASHRAE 241

We've established that we have the tools to reduce airborne diseases in indoor environments. But what does it look like to successfully use these tools? Thankfully, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) discussed these practical details in depth in ASHRAE 241, a standard that explains the minimum requirements a building should satisfy to reduce the spread of airborne diseases.

All indoor rooms need to have clean air flowing into them. The per-person clean airflow rate needs to be above the minimum required to successfully mitigate airborne diseases.

The first step is to determine the minimum per-person clean airflow rate. This is also called the per-person clean air delivery rate (CADR). This rate depends on the occupancy category of the room. For example, the minimum per-person CADR is 40 cubic feet per minute (CFM) for a classroom, 50 CFM for a residential common space (like an apartment lobby), and 90 CFM for a healthcare waiting room. See the table 5-1 from ASHRAE 241.

Occupancy Category	CFM/person	lps/person
Correctional Cell	30	15
Correctional Day Room	40	20
Food & beverage facilities	60	30
Gym	80	40
Office	30	15
Retail	40	20
Transportation Waiting	60	30
Classroom	40	20
Lecture Hall	50	25
Manufacturing	50	25
Sorting, packing, light assembly	20	10
Warehouse	20	10
Healthcare Exam Room	40	20
Healthcare Group Treatment Area	70	35
Healthcare Patient Room	70	35
Healthcare Resident Room	50	25
Healthcare Waiting Room	90	45
Auditorium	50	25
Place of Religious Worship	50	25
Museum	60	30
Convention	60	30
Spectator Area	50	25
Lobbies	50	25
Residential Common Space	50	25
Residential Dwelling Unit	30	15

Figure 2 - Table 5-1 from ASHRAE 241, provided by Joey Fox (link)

The next step is to figure out how many people will be in the room. Then, we multiply that number of people by the per-person CADR. This tells us the overall CADR we need in the room. For example, a classroom that holds 30 people will need a CADR of 1200 CFM (30 persons x 40 CFM per-person).

Now we know the CADR that a room requires, and we need to compare it to the actual CADR of the room in its current state.

Clean airflow comes from three main sources:

- In-room air cleaners (air purifiers)
- Central ventilation or air cleaning system
- Open windows (natural ventilation via outdoor air)

We need to add up the CADR from these sources. If the total CADR is too low, we have two options: we can reduce the occupancy of the room, which lowers the CADR necessary to mitigate airborne transmission, or we can increase the CADR of the room.

To increase the room's CADR, we'll need to do one or more of the following: increase natural ventilation (adding openable windows and consistently using them), increase the flow and/or filtration of the ventilation system, or increase the amount of in-room air cleaning (add air purifiers).

Simple Example

Let's revisit our classroom example. Suppose natural ventilation is unavailable, and our only source of clean airflow is the ventilation system. We need to know what rate of airflow it provides and what fraction of that air is cleaned. Then, we multiply them together. That tells us how much clean airflow is provided by the ventilation system.

Suppose we find out that the ventilation system provides a flow rate of 450 CFM into the classroom. We also discover that, like many ventilation systems, it uses MERV-13 filters (which have a 77% filtration efficiency). To figure out the clean airflow provided by this system, we just multiply the flow rate by the filtration efficiency: 450 CFM x 0.77 = 346.5 CFM. This tells us the CADR of the ventilation system.

Since the ventilation system is the room's only source of clean air, that means the total CADR for the room is 346.5 CFM. This is 853.5 CFM below what is required to effectively mitigate airborne disease transmission. We need to increase the room's CADR. Since natural ventilation is unavailable, our options are to A) increase the flow rate of the ventilation system, and B) use more in-room air cleaning devices (like air purifiers).

Let's focus on option B – we will increase the room's CADR by adding air purifier devices.

Now we need to select an air purifier. Purifiers that are powered by PC fans are a great choice, because they supply ample airflow at much lower volumes. For this example, we need a lot of additional CADR, so something like the Tower of Power by Clean Air Kits might be appropriate (note: the authors of this report have no financial relationship with this company). The product page indicates that this purifier provides a CADR of ~400 CFM. With two of these devices, the room's CADR will be very close to the minimum level (now just 53.5 CFM away), drastically reducing the risk of airborne transmission.

We could also consider adding one additional device, such as the 5-fan version of the Luggable by Clean Air Kits, which provides a CADR of 211 CFM. With this addition, the CADR of the room would be comfortably above the minimum level required to reduce airborne disease transmission.

Placement of Air Purifiers

Air purifiers work best when the air in the room is moving around and mixing well. To ensure this, we should consider using fans (ideally, ceiling fans) to generate air movement in the room. We should also place the purifiers toward the middle of the room and away from walls.

As Joey Fox, a professional HVAC engineer, explains:

> "If the clean air from the air cleaner doesn't mix well with the air in the space and simply circulates back to the intake, its effectiveness is reduced…
>
> To ensure optimal air distribution, use fans to promote air mixing, but be cautious about creating direct currents between people. Ceiling fans are ideal for achieving proper air mixing without generating horizontal currents…
>
> Using HEPA filters that blow upward also prevents creation of direct currents between people… Position air cleaners away from walls or obstructions and closer to the center of the space to ensure proper mixing of clean air throughout the area." (source)

As Joey Fox points out, an ideal device would be ceiling mounted and controlled remotely - that way occupants could not turn the device off. Unfortunately, affordable ceiling-mounted air purifiers that use quieter PC fans are not widely available, though this may change in the future. Thankfully, the portable air cleaners discussed above are excellent alternatives, efficiently providing clean air at reasonable volumes.

As you can see, we have the technology and the knowledge to dramatically reduce airborne disease and provide cleaner indoor air. We need to advocate for these tools to be implemented and used consistently, and we should try to increase awareness of the harms of airborne disease.

What can we learn from history?

Our history shows us that we have a strong tendency to reject new knowledge about infectious disease and microorganisms - especially when that knowledge suggests we need to change our behavior. See the following examples.

> In 1847, Ignaz Semmelweis showed that handwashing could reduce the spread of disease; he was ridiculed for this, and the idea wasn't accepted until after his death some 20 years later.
>
> In 1854, John Snow demonstrated that cholera was spread by microbes that live in the water, and that sanitizing the water would reduce outbreaks; people pushed back, in part due to concerns that sanitizing water would hurt the population's natural immunity. Snow's idea wasn't accepted until more than 30 years later.
>
> In 1861, Louis Pasteur shared his discovery of germ theory with the world. Society pushed back against using pasteurization techniques to sterilize milk, claiming that the milk tasted "cooked" and was less nutritious. Even 80 years later, people still took issue with pasteurization, believing that the increased hygiene would weaken the population's natural immunity.
>
> In 1882, Robert Koch provided strong evidence that tuberculosis was caused by a microorganism and that it was airborne. The airborne spread theory was not widely accepted until nearly 50 years later, which eventually led to the practice of isolating infected patients from the uninfected.

These examples show a clear pattern: we tend to resist new medical knowledge that suggests we need to change our behavior, especially if that knowledge relates to infectious disease. We tend to resist knowledge that emphasizes the importance of maintaining a clean environment (i.e. water and air) through hygienic practices, often out of a fear of losing natural immunity.

Thankfully, we live in a world where we can easily access modern research and historical records. Using this knowledge, we can avoid falling prey to these tendencies and accelerate our efforts to innovate and to alleviate preventable suffering.

Should vaccinated people wear masks?

Vaccines are a powerful public health tool, helping to reduce severe outcomes of infections, but their ability to prevent infection is limited. Due to the rapid evolution of COVID-19, both vaccinated and unvaccinated individuals can efficiently spread the disease and harm the vulnerable. Being vaccinated is not enough to ensure essential indoor spaces are accessible to the vulnerable.

> "2024-2025 COVID-19 vaccines… VE (vaccine effectiveness) was low against laboratory-diagnosed SARS-CoV-2 infection (16.60%)" (source)
>
> "Continued mitigation approaches (e.g., wearing masks and social distancing) are warranted even in fully vaccinated individuals to prevent transmission." (source)
>
> "For Omicron BA.1 breakthrough cases, reduced infectious VL (viral load) was observed only in boosted but not in fully vaccinated individuals compared to unvaccinated individuals." (source)
>
> "Effectiveness [of the 2023-2024 vaccine] at preventing [COVID] infection decreased to 32.6% after 10 weeks and 20.4% after 20 weeks." (source)
>
> "We found no significant difference in cycle threshold values between vaccinated and unvaccinated persons infected with severe acute respiratory syndrome coronavirus 2 Delta" (source)

It's worth noting that the measles vaccine is much more effective at preventing infections than vaccines for other pathogens (such as COVID-19), at least at the present (January, 2026). Even so, vaccinated individuals make up a meaningful fraction of measles cases overall. From 2002-2021, about 12% of measles cases in the US were in vaccinated individuals. This means that vaccinated people can still become infected and spread the virus. In fact, immediately after vaccination, individuals have an 8% chance of getting infected with measles if they have had one dose; for 2 doses, the risk is closer to 5%. That risk increases over time as the vaccine's effectiveness wanes.

Wearing an N95-grade respirator in essential indoor spaces is a much more reliable way to reduce harm than being vaccinated. Respirators drastically reduce the chance that the wearer becomes infected and brings an illness home. Unlike vaccines, these devices can actually prevent airborne pathogens from being inhaled and entering the body. Also, respirators minimize the amount of infectious air that infected individuals exhale into the room; they act as a form of source control. This results in cleaner and safer indoor air, and they work against all airborne infections: influenza, RSV, COVID, measles, tuberculosis, streptococcus pneumoniae, mycoplasma pneumoniae, and colds (rhinoviruses and coronaviruses).

> "[respirator] filtration efficiency is based on particle size rather than the nature of the particle's origin" (source)
>
> "Relative efficacy of masks and respirators as source control for viral aerosol shedding from people infected with SARS-CoV-2… A duckbill N95 reduced exhaled viral load by 98%, and significantly outperformed a KN95 as well as cloth and surgical masks" (source)
>
> "We attribute the lower rate of healthcare-acquired infections in part to providing universal source control via masking, thereby mitigating the spread from asymptomatically infected or minimally symptomatic individuals." (source)

In the past, people could avoid spreading illness in public by simply staying home when they felt ill. This approach is far less reliable now that COVID-19 has emerged. That widespread illness has a 20-40%

chance of being asymptomatic, and asymptomatic infections are a large driver of transmission (explaining 25% to 60% of transmission events). As a result, symptoms are a much less reliable indicator of whether someone poses an infection risk to others.

> "A systematic review and meta-analysis... By analyzing over 350 studies, we estimate that the percentage of (COVID) infections that never developed clinical symptoms, and thus were truly asymptomatic, was 35.1%" (source)
>
> "...asymptomatic people are the main route of transmission of the COVID-19 disease" (source)
>
> "... transmission of SARS-CoV-2 Omicron variant in Shanghai, China… 57.2% of the transmission events occurring at the presymptomatic phase." (source)
>
> "…transmission among agricultural workers and their households in Guatemala, 2022-2023… A total of 27% of transmissions occurred from asymptomatic or pre-symptomatic individuals." (source)
>
> "Under baseline assumptions, approximately 59% of all transmission came from asymptomatic transmission: 35% from presymptomatic individuals and 24% from individuals who are never symptomatic." (source)
>
> "Studies have shown that the viral load in the upper respiratory tracts of asymptomatic infected persons is comparable to that of symptomatic individuals" (source)

Unlike vaccines, respirators are just as effective against newer strains as they are against previous ones; they only depend on unchanging characteristics of infectious particles, such as their size and electric charge. In contrast, vaccine efficacy declines as pathogens mutate. Developing vaccines takes time, so these products are always lagging the most recent strains in circulation, making them far less reliable than respirators at preventing infection.

> "three 'mechanical' collection mechanisms operate to capture particles [in respirators]: inertial impaction, interception, and diffusion… In some fibrous filters constructed from charged fibers [like N95s], an additional mechanism of electrostatic attraction also operates... Respirator filters must meet stringent certification tests" (source)
>
> "[respirator] filtration efficiency is based on particle size rather than the nature of the particle's origin" (source)
>
> "Studies of cough aerosols and of exhaled breath from patients with various respiratory infections have shown striking similarities in aerosol size distributions, with a predominance of pathogens in small particles (<5 µm)" (source)
>
> "As SARS-CoV-2 (COVID) continues to evolve, it is likely that both existing and updated variant-specific vaccines will lag viral antigenic evolution." (source)
>
> "Given the 12-month lag between the decision to update an influenza vaccine and the peak of the following influenza season… the clades circulating 12 months after the vaccine decision can be antigenically distinct from clades that were circulating at the time of the decision." (source)

Some commentators argue that one-way masking is sufficient; the idea would be that only those who are especially vulnerable to infections should have to wear respirators in indoor public spaces. However, there are two major issues with this approach. First, it contradicts universal moral values: the healthy should avoid harming the vulnerable whenever they can, especially if doing so has very low risks, as is the case for wearing respirators. Secondly, one-way masking is much less effective at reducing infection risk compared to multi-way masking (i.e. other people wearing respirators as well).

> "source control (mask on the Source) was often 3–300 times more effective than a mask on the Receiver." (source)
>
> "If only the susceptible wears a face mask with infectious speaking at a distance of 1.5 m... with an FFP2 [N95] mask, it [infection risk] remains at about 20% even after 1 h… When both wear a well-fitting FFP2 mask, [the risk] is 0.4%... We conclude that wearing appropriate masks in the community provides excellent protection for others and oneself." (source)
>
> "With cough, source control (mask or respirator on Source) was statistically superior to mask or unsealed respirator protection on the Receiver (Receiver protection) in all environments… Source control… may be an important adjunct defense against the spread of respiratory infections." (source)

How much longer do we need to wear masks?

Current State of Affairs

People who wear masks in public are likely to hear this question: "When are you going to stop wearing masks?" The answer is quite simple: "When we don't benefit from their protection."

Since masks are worn to avoid a hazard (like airborne illnesses), the rational approach is to wear them in areas where that hazard is present. Thankfully, the risk of catching and spreading airborne disease is not always high; it is situational and fairly easy to predict. For example, we know that these infections are less common in areas that have good ventilation and are sparsely populated. In contrast, we know that airborne infections are a major risk in a few key situations:

- Crowded, poorly-ventilated indoor areas like public transit and busy shops
- Areas with individuals who are especially vulnerable to infection (like hospitals and medical clinics)
- Periods of time when sickness usually spikes, or when it is being widely reported (typically, during the colder months)

We also know that the risk of spreading airborne infections is highest when we are actively sick. In that case, wearing a mask significantly reduces the odds of infecting others and causing more harm.

If we were to only wear masks in these high-risk situations, that change alone would dramatically reduce airborne diseases in the community. Even small increases in masking can make a meaningful difference.

> "Slight increases in mask adherence and/or efficacy above current levels would reduce the effective reproductive number (R_e) substantially below 1… [this] results in a significant reduction in transmission with widespread implementation… particularly if implemented comprehensively in potential super-spreader environments." (source)
>
> "We determine the probable impact of wearing face masks on trains over a seven-day simulation horizon, showing substantial and statistically significant reductions in new cases when passenger mask wearing proportions are greater than 80%. The higher the level of mask coverage, the greater the reduction in the number of new infections. Also, the higher levels of mask coverage result in an earlier reduction in disease spread risk." (source)

This is particularly important for influenza and SARS viruses (like COVID-19), since they can transmit via "superspreader" events, where a small number of infected people spread the pathogen to a large group of people. A single avoided infection can prevent a new group of infections from occurring.

> "Indoor activities... have been characterized as potential superspreading events, and such events are the major drivers of the COVID-19 pandemic" (source)
>
> "Controlled human influenza infection reveals heterogeneous expulsion of infectious virus into air… The observed heterogeneity… suggests features of human influenza that may contribute to superspreading dynamics" (source)

When deciding when to wear a mask, it helps to ask the following: "Am I getting some kind of reward if I skip the mask and risk an infection?" That may well be the case in social situations, like when we're spending quality time with family or friends. But some situations don't provide any rewards for skipping, like waiting in line at a crowded pharmacy or post office. In those cases, wearing a mask is a sensible choice.

Looking to the Future

Once engineering controls are consistently implemented and robust enough to mitigate airborne transmission (meeting standards like ASHRAE 241), wearing masks will be largely unnecessary in non-medical areas. This outcome might take time, but economic incentives make it highly probable. Airborne infections impose a significant burden on the economy, so authorities are incentivized to reduce these illnesses; improving engineering controls is the most efficient way to do so.

In fact, this is already becoming more commonplace. Decision makers are becoming increasingly aware of the benefits of using engineering controls like ventilation to improve indoor air quality and reduce the spread of airborne disease.

> In 2020, the state of New York required that all shopping malls update the filtration in their ventilation systems, requiring MERV filters that are able to capture airborne pathogens.
>
> In 2021, Salesforce increased the flow and filtration of its ventilation systems, and a year later it obtained a certification for its disease mitigation efforts. London's transportation agency updated its buses so that portions of their windows are permanently open to promote better natural ventilation. Google redesigned its office spaces to maximize its use of fresh outdoor air.

> In 2022, federal buildings in the United States imposed new ventilation standards that required all systems to use MERV-13 filters or better. Schools in California and North Carolina spent millions to upgrade their ventilation systems, and Boston's school district installed thousands of air quality monitors so building managers can quickly identify deficient ventilation.
>
> Ahead of the 2023 World Economic Forum meeting in Davos, Switzerland, the organizers installed HEPA air purifiers and a state-of-the-art ventilation system to lower the transmission of airborne illnesses.

In a world of robust engineering controls, wearing masks can still provide additional benefits in a few situations, such as when we are actively sick. Additionally, masks can nearly eliminate the chance of transmission during close-range interactions (those within 1 or 2 meters). While ventilation helps lower infection risk at both short and long distances, infection risk in ventilated areas can still be moderate at close range. This makes masks a sensible choice in crowded areas.

> "…as the distance decreases from 2 m, a rapid rise is seen in the required ventilation. There also exists a threshold distance below which general ventilation cannot be used to control short-range exposure [around 1 m]." (source)
>
> "Despite good air quality (mean CO_2 614 ppm), 39% of air samples had SARS-CoV-2 (COVID) RNA" (source)
>
> "Moreover, the air change rate [a proxy for ventilation] in air cabins can range from 15 to 20 per hour due to small volume, and the high-efficiency particulate air filter used in the airplanes can remove 99.97% of the particles with a radius larger than 0.3 µm… the inflight SARS-CoV-2 (COVID) attack rates ranged from 2.6% to 16.1%... the short-range airborne route is more appropriate to explain the inflight outbreaks of SARS-CoV-2 and influenza A(H1N1)pdm09 virus." (source)

The future holds much promise as air-cleaning technology becomes more commonplace and better deployed. In the meantime, we can strategically use masks to protect ourselves and prevent outbreaks in the community.

How safe are masks?

A major advantage of respirators is that they are safe devices; therefore, the potential risks of using them are quite low.

> "Respiratory and cardiovascular effects of N95 and other FFRs have been extensively studied in healthy adults including pregnant women. The reported effects generally have small magnitude and are likely to be well-tolerated by normal persons." (source)
>
> "A Systematic Review… in the General Population… The overall consensus is that there are no attributable negative consequences from the use of N95 masks in the short to medium term." (source)
>
> "...with long-term respirator use among medical intensive care unit nurses… changes were not clinically relevant… Long-term use of respiratory protection did not result in any clinically relevant physiologic burden for health care personnel." (source)

Some commentators have expressed concerns about getting infected by touching face coverings. However, this infection route has very little supporting evidence.

> "Minimal influenza virus transmission from touching contaminated face masks: a laboratory study… Despite being exposed to high levels of virus contamination on the masks, very little or no viable virus was successfully transferred from the mask to the finger in these experiments… the risk of viral transmission via this fingertip-mask surface-touching route appears extremely low—in contrast to commonly cited infection control guidance" (source)
>
> "What proportion of healthcare worker masks carry virus? A systematic review… No study reported clinical respiratory illness as a result of virus on the masks… current evidence suggests that viral carriage on the outer surface of surgical masks worn by HCW treating patients with clinical respiratory illness is low and there was not strong evidence to support the assumption that mask use may increase the risk of viral transmission." (source)
>
> "Of the 52 masks received for testing, only one batch… showed any PCR positive results (for rhinovirus)... absence of detection of SARS-CoV-2 (COVID) RNA on any of the mask surfaces" (source)

This is unsurprising, since there isn't much empirical support suggesting that respiratory infections are likely to spread via surfaces (fomites).

> "Transmission route of rhinovirus [the cause of common colds]… A systematic review… We found low evidence that transmission via hands and fomite followed by self-inoculation is the dominant transmission route… This suggests that the major transmission route of RVs in many indoor settings is through the air" (source)
>
> "the risk associated with [influenza] transmission through contact with fomites is hypothetical, lacking solid quantitative evidence… We found that viable viruses were rarely transmitted to fingertips from the above fomites even when the viral loads in the viral fluid contaminating the fomites far exceeded that seen in real life… Consequently, we conclude that the probability of contact transmission of influenza via dried fomites is negligible or minimal" (source)
>
> "fomite transmission is an unlikely transmission route for enveloped respiratory viruses (note: this category includes influenza, RSV, and coronaviruses [like COVID])" (source)
>
> "Transmission [of rhinoviruses] via fomites heavily used for 12 hr by eight donors was the only possible route of spread, and no transmissions occurred… These results suggest that contrary to current opinion, rhinovirus transmission, at least in adults, occurs chiefly by the aerosol route." (source)
>
> "… the [measles] virus does not survive long on fomites as it is quickly killed by heat and ultraviolet radiation." (source)
>
> "In a comprehensive investigation of shipboard [tuberculosis] transmission on a United States Navy vessel… Shared air fully accounted for the patterns of transmission seen… no evidence was found… of transmission through dust or fomites" (source)
>
> "M. pneumoniae is principally transmitted by aerosol inhalation of droplets" (source)

> "Pneumococcus (Streptococcus pneumoniae) resides primarily in the upper respiratory tract and is transmitted via aerosolized droplets." (source)

Can masks be reused?

Note: the authors of this report have no financial relationships with the manufacturers of any products listed in this section or anywhere else in this document.

Many N95 respirators and other masks are disposable, so they work best when they're worn once. However, they can be reused. If they still have a fairly tight seal with the wearer's face, they can continue to offer protection. One study found that after two uses, ~90% of the N95-rated respirators still had excellent filtration efficiency (>95% for particles around 70 nanometers in diameter).

For protection against respiratory pathogens, you don't need to try to decontaminate respirators after each use; in fact, there's very little evidence supporting the idea that respiratory pathogens can spread via mask surfaces (see this systematic review). It can help to rotate through multiple masks, that way each one has a chance to dry before being used again. N95-rated respirators have slightly worse performance when damp (see here and here).

Just remember that having a tight seal is critical; once you notice the seal is declining, it's time to get a new one. The CDC advises reusing these respirators no more than five times per device. Respirators that are more rigid, such as Moldex respirators, may have a better chance at maintaining a good seal when reused.

Alternatively, a more environmentally friendly option is to use a respirator that has replaceable filters. These filters typically last for multiple uses, and they result in a lot less waste when they need to be replaced. One option is the Flo Mask Pro; it has cloth straps that go behind the head, and it comes in two sizes (kid and adult). This device can use filters that meet N95 or N99 standards (your choice). The device itself is rigid and designed to fit most face types (supposedly around 90%), but it won't fit everyone.

Another option is an elastomeric respirator (like this one), which is more tight fitting and uses filter cartridges. These devices are unnecessary when you just need protection against bioaerosols. Their main benefit is that they provide better protection against ultrafine particles (they meet the P100 standard), and that they can protect against additional threats such as toxic gasses, as long as you use the right filter cartridge (like this one). Ultrafine particles are a common hazard found in industrial settings. In wildfires and other sources of air pollution, ultrafine particles and toxic gasses (such as volatile organic compounds [VOCs]) are significant hazards.

> "Occupational exposures (to ultrafine particles [UFPs]) will be particularly high during high temperature operations (e.g., welding, smelting), high-speed manufacturing, and combustion processes" (source)
>
> "The second-largest source of VOC pollutants is biomass burning, which includes wildfires." (source)
>
> "Generally, the inorganic gases and VOC emission factors are one to three orders of magnitude greater from urban fuels compared with biomass. (source)

> "The emissions from WUI (Wildland-Urban Interface) fires are characterized by their high content of ultrafine particles (UFPs, <100 nm), which dominate particle number concentrations (77–90 %, reaching 1.25 × 105 particles/cm3)." (source)

Keep in mind that the general public may find elastomeric respirators jarring to look at relative to disposable respirators, which are more commonplace. They might appear especially jarring when there is no obvious emergency taking place, such as a wildfire or nearby industrial fire.

Is COVID-19 endemic now?

A disease becomes endemic when A) its prevalence is lower than the pandemic stage, B) its spread is stable and predictable, and C) it is no longer spreading in multiple countries at the same time. See the definitions below.

> "The endemic state refers to the stable maintenance of the pathogen, typically at a lower prevalence… The change from epidemic to endemic phase is thus characterized by a dramatic reduction in the prevalence of infection" (source)
>
> "Endemic refers to the constant presence and/or usual prevalence of a disease or infectious agent in a population within a geographic area… Pandemic refers to an epidemic that has spread over several countries or continents, usually affecting a large number of people" (source)
>
> "A disease outbreak is endemic when it is consistently present but limited to a particular region. This makes the disease spread and rates predictable" (source)

Available data on COVID-19 circulation does not align with those conditions. Namely, conditions A (low prevalence) and C (no longer spreading worldwide) are not in place today.

Unfortunately, since COVID-19 entered the scene, we have failed to meaningfully reduce its incidence. This is unsurprising given the fact that it is airborne, and the fact that airborne precautions (like wearing respirators) are not widely implemented. Official counts of COVID-19 cases are now severely underestimated, since labs and hospitals are no longer required to report COVID-19 cases to the government. As a result, the best available estimates for case counts come from wastewater data. Based on that data, since 2021 every major COVID-19 wave has had peak case counts that surpassed the peak case count in the initial 2020 worldwide wave.

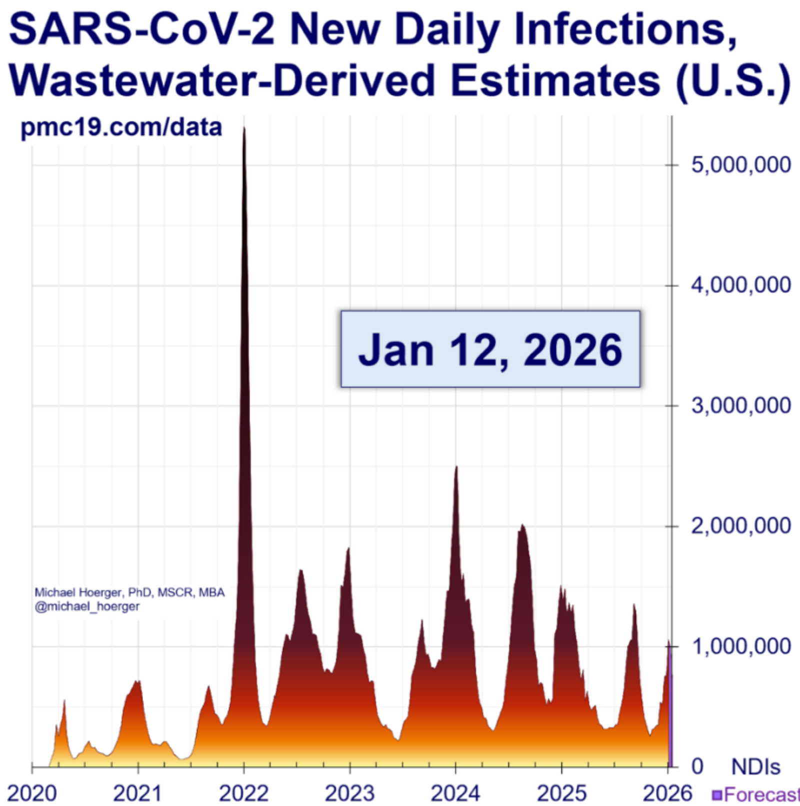

Figure 3 - New Daily COVID Infections, Estimated via Wastewater Data (link)

Also, we have evidence that COVID-19 is still spreading globally. The WHO's May 2025 Global Situation report acknowledged that "global SARS-CoV-2 activity has been increasing, with the test positivity rate reaching 11%, levels that have not been observed since July 2024. This rise is primarily observed in countries in the Eastern Mediterranean, South-East Asia, and Western Pacific." This indicates a rise in prevalence that transcends international boundaries.

What about the Cochrane review of mask RCTs?

Some commentators have argued that masks don't work. When making this claim, they often point a review from the Cochrane Collaboration. This review considered randomized clinical trials (RCTs) that tested the effect of policies that promoted mask wearing.

To show that masks don't work, we would need to perform physical tests and see that they do not operate as designed - that they fail to filter small particles. The studies in Cochrane's review did not do this. Instead, they assessed the effect of policies that recommended masks.

Unsurprisingly, even the Cochrane Collaboration itself agrees that their review does not show that masks don't work.

> "Many commentators have claimed that a recently-updated Cochrane Review shows that 'masks don't work', which is an inaccurate and misleading interpretation.

> It would be accurate to say that the review examined whether interventions to promote mask wearing help to slow the spread of respiratory viruses, and that the results were inconclusive. Given the limitations in the primary evidence, the review is not able to address the question of whether mask-wearing itself reduces people's risk of contracting or spreading respiratory viruses." (source)

The Cochrane Collaboration also admitted that many of the study participants did not actually follow the masking policy. A large fraction of participants who were supposed to wear a mask actually did not. This is called "low adherence."

> "The review authors are clear on the limitations in the abstract: 'The high risk of bias in the trials, variation in outcome measurement, and relatively low adherence with the interventions during the studies hampers drawing firm conclusions.'
>
> …Adherence in this context refers to the number of people who actually wore the provided masks when encouraged to do so as part of the intervention. For example, in the most heavily-weighted trial of interventions to promote community mask wearing, 42.3% of people in the intervention arm wore masks compared to 13.3% of those in the control arm." (source)

This review does not inform us regarding the performance (filtration efficiency) of masks, which can only be demonstrated by physical tests. Instead, it shows us that the success of mask policies can be significantly reduced by other factors, such as inconsistent adherence or improper fit. As an article from the journal *History and Philosophy of the Life Sciences* explains:

> "A simple germ theory of disease suggests that masks will have some effectiveness and therefore unsupportive findings from RCTs do not refute the case for masks per se, but instead draw attention to mediating and interacting factors that may be manipulable…
>
> If the basic mechanistic function of masks is accepted, then the failure of sufficiently high quality RCTs to show a significant effect is likely to be due to other factors that are offsetting this direct effect. But such factors may themselves be manipulable." (source)

A common misconception is that RCTs are more valuable than other types of evidence. In reality, each type of evidence has strengths and weaknesses. RCTs are most helpful when researchers want to test an intervention and they don't have a clear idea of why it might work; this is typical when companies are developing a pharmaceutical product (like a medication or vaccine). In contrast, RCTs are far less helpful when we want to test something that depends on physical theories that we can clearly demonstrate – in those cases, experimental tests (mechanistic studies) are far more relevant.

> "RCTs (randomized clinical trials) do indeed require minimal assumptions and can operate with little prior knowledge. This is an advantage when persuading distrustful audiences, but it is a disadvantage for cumulative scientific progress, where prior knowledge should be built upon, not discarded." (source)
>
> "Clinical trials are supposed to require equipoise: genuine uncertainty about which intervention is better. If we already have good reason to believe a treatment works, randomizing people to a placebo means knowingly denying them benefit… That's harm in the name of methodological purity." (source)

> "Systematic reviews of high quality randomized trials generally count as the 'best evidence'. However, well-conducted randomized trials are sometimes unavailable, unfeasible, unethical or unnecessary. In such cases other forms of evidence must be considered." (source)
>
> "Mindlessly ascribing greater validity to a study based on a hierarchy of designs is fallacious. For example, the relation between cigarette smoking and lung cancer is well established, based on findings from cohort and case–control studies. The connection was never shown clearly in a randomized trial… the discrepancy was ascribed to problems with the trial." (source)

Like many safety devices, respirators and other masks depend on well-modeled physical theories that can easily be falsified. Therefore, when evaluating these devices, mechanistic studies are much more relevant than RCTs. This explains why RCTs weren't required during the development seatbelts, water sanitation systems, condoms, aircraft safety systems, and many other safety devices and systems that society depends on daily.

> "Aerosol filtration by fibrous filters… The experimental results, together with similar results reported by other investigators, were compared with the theoretically predicted values and good agreement was found." (source)
>
> "Experimental study of aerosol filtration… theories taking into account the interference effect of neighboring fibers are in reasonable agreement with the experiment" (source)
>
> "Three 'mechanical' collection mechanisms operate to capture particles [in respirators]: inertial impaction, interception, and diffusion… In some fibrous filters constructed from charged fibers [like N95s], an additional mechanism of electrostatic attraction also operates.... Respirator filters must meet stringent certification tests." (source)
>
> "Overall, filter efficiency and faceseal leakage determine [the respirator's] TIL [total inward leakage]. (source)

What about Sweden?

Many commentators have claimed that Sweden's pandemic response, which was unusually relaxed, is evidence that infection control is largely unnecessary and that COVID is less harmful than many people think. Sweden allowed bars, restaurants, and schools to stay open while the rest of the world implemented shutdowns and strict quarantines.

Proponents of this strategy argue that Swedish citizens' immune systems benefited from the higher exposure to infections.

However, years later, Sweden has repeatedly experienced widespread illness that has disrupted its society. For example, in early 2022 many countries throughout Europe saw widespread illness during the Omicron wave. Like them, Sweden encountered pervasive sickness, resulting in:

- 50% of the trains in Stockholm being cancelled (source)
- 30% of negotiations in Swedish courts being delayed (source)
- A key payment system of the central bank being exposed (source)
- 15% of public transit workers calling out sick (vs 5% in normal times) (source)

- Students being sent home because nearly all the teachers were sick (source)

Additionally, by 2023, a substantial fraction of young adults in Sweden reported persistent breathing and cognitive issues. And by the end of 2023, the widespread circulation of viruses put a strain on acute care hospitals, which were especially under pressure due to staff members calling in sick.

> "In the 18–24 age group, 32 percent experience brain fog… The most common registered symptoms in Sweden's patient register so far are problems with lung function or breathing, brain fatigue or cognitive impairment" (source)
>
> "In December… Several viruses such as influenza, COVID-19 and RS virus were in circulation and posed a strain on the health service. The strained situation became tougher by an increased sick leave among employees." (source)

Then, in 2024, Sweden saw a massive surge in a bacterial pneumonia that predominantly affects younger people (mycoplasma pneumonia [MP]). The prevalence of MP hit a 26-year record high, with one physician remarking that "the number of intensive care is being held at a level that I have never seen in my years as an infectious disease doctor." MP hospitalizations hit a 10-year record high. This surge is consistent with a population that has weakened immune systems; frequently recurring bacterial pneumonia is actually considered an AIDS-defining illness.

Proponents of natural infections may claim that the MP surge isn't a result of immune system issues; it's actually a result of (1) a prolonged under exposure to it in 2020, and/or (2) the typical cycles of MP transmission. However, these ideas are invalidated by what we know about Sweden's response and about MP itself.

- MP infections are most common in school-aged children and adolescents, and in Sweden, schools remained open and young people's movement was largely unconstrained. This is inconsistent with the idea of insufficient exposure.
- Data from Denmark, the US, and Japan indicates that MP waves often occur in 3–5 year cycles; those cycles don't explain MP cases hitting a multi-decade record high.
- Natural infections of MP are unlikely to stop surges of MP happening years later. Reinfections are quite common, and most cases incur immunity that quickly wanes after 2 years on average.

Finally, we should note that Sweden had the highest per-capita rate of COVID deaths compared to its Scandinavian neighbors, Denmark and Finland. While its per-capita rate still falls below that of the United States, its population density is significantly (~43%) lower.

Given Sweden's history of problematic data reporting, that death count is likely an underestimate. Leaders in Sweden resisted efforts to transparently share data about transmission and prevalence.

> 'The number of available ICU beds per region was not publicly available, and regions were unwilling to share information on the spread of the infections to the municipalities.'
>
> 'Many schools did not inform parents or even teachers about confirmed COVID-19 transmission on the premises, nor reported it to official agencies, and urged parents not to tell if their children were infected — since this would "spread fear." ' (source)

Anders Tegnell, Sweden's State Epidemiologist in 2020, has repeatedly made inaccurate statements that minimized the impact of the virus. In March 2020, when COVID was spreading globally and there were already more than 100,000 cases, Tegnell claimed that this virus was unlikely to cause "a 'classic' pandemic with a lot of sick people around the world at the same time." When critics in Sweden expressed concern over more than 100 people dying a day from COVID, Tegnell falsely claimed that the real figure was lower (around 60), but the updated government figures found that the actual burden was in fact more than 100 a day.

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