Making sense of the research on COVID-19 and masks

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Scientific evidence can be difficult to interpret under the best of circumstances. During a global pandemic (and election year), it is no surprise that there is public confusion about what measures can effectively protect families and communities from COVID-19. Because the scientific and medical understanding of this disease is advancing so rapidly, we decided to put together a plain-language summary of the science on face coverings—a.k.a. masks. As lifelong residents of Utah County and scientists, we felt a responsibility to respond to the technical questions asked by friends and family. We did not receive any funding to carry out this work, nor do we plan on seeking financial support on this topic (our BYU lab mainly researches water and air pollution: benabbott.byu.edu). Our four-person team compiled and read over 115 scientific studies on COVID-19. These studies were done by independent groups from all around the U.S. and the world. In the paragraphs below, we have done our best to accurately reflect the scientific evidence, pointing out where it is solid and where there is still uncertainty. There are three sections, with increasing levels of detail: 1. An executive summary, 2. A list of common questions, and 3. A deep dive. We hope this summary is useful to you as you decide what is best for your family and as our community decides how best to face this threat together.

Executive summary:

1. In the first few months of the pandemic, there was scientific uncertainty about the usefulness of public masking. Conflicting guidance was given by several official sources[1–3].
2. There is now convincing evidence from multiple controlled experiments[4–6] and field observations[7–11] that wearing masks reduces the transmission of COVID-19 for healthcare workers and the public. Most of this evidence is COVID-19 specific and has emerged in the past few months[1,7].
3. Masks prevent infected people from spreading the virus to others by trapping the respiratory droplets (tiny moisture particles) that are produced when we cough, speak, and breathe[10,12,13]. Cloth masks can stop 90% or more of the dispersal of droplets carrying the virus[12,14]. There is some evidence that cloth masks also protect the wearer from infection[7,8], though this is less certain.
4. Masks are highly safe, with only minor and uncommon side effects[1,15,16]. In addition to many medical studies, public masking has been proven safe among children, adults, and the elderly in cultures where this practice has long been common[10,17]. However, some sensitive individuals should not wear masks, such as those with compromised respiratory systems[18] and individuals who cannot remove or adjust their own masks (children under 2 and people with severe disabilities)[13].
5. Researchers from hospitals, universities, the private sector, and government agencies have concluded that **masks could be one of the most powerful and cost-effective tools to stop COVID-19 and accelerate the economic recovery**[1,4,5,9,10,17]. There is universal agreement, however, that masking alone will not be enough to stop the pandemic. Masking is most effective when combined with physical distancing, frequent handwashing, rapid testing, and coordinated contact tracing[1,7,19].

Common Questions:

What is COVID-19? Coronavirus disease 2019 (COVID-19) is caused by a respiratory virus named "severe acute respiratory syndrome coronavirus 2" (SARS-CoV-2). It is in the same family as the virus that caused the SARS outbreak of 2003, and both of the viruses appear to have originally come from bats[20,21]. The "severe" part of the virus's name comes from its extreme contagiousness and serious complications.

Thankfully, most people who have COVID-19 only experience flu-like symptoms such as fever, cough, difficulty breathing, and fatigue. However, COVID-19 is much more contagious than the flu, and it has a much higher death rate: 0.3 to 5.7% based on the most reliable estimates[22–26]. For reference, the common flu has a death rate of 0.1%. Serious COVID-19 complications include damage to the lungs, liver, and heart, permanent loss of taste and smell, blood clots, stroke, and death[24]. The rate of complications including death is much higher in individuals with preexisting conditions, particularly the elderly and those with cardiovascular disease, diabetes, respiratory conditions, high blood pressure, cancer, an organ transplant, sickle cell disease, immune disorders, and those living in areas with more air pollution[26–28].

Don't take our word for it

The research cited in this report comes from independent medical teams from around the world. Having multiple groups investigate the same question and comparing their independent conclusions increases the reliability of the science. To make it easier for you to evaluate the strength of this evidence, we have compiled PDFs of each cited study in this online folder. To get started, **here are five of the most definitive scientific studies on public masking and COVID-19**:

1. *Face Masks Against COVID-19* (in review at PNAS)
2. *Face masks for the public during the COVID-19 crisis* (BMJ)
3. *Universal masking to prevent SARS-Cov-2* (JAMA)
4. *Face masks and GDP* (Goldman Sachs Research)
5. *Universal masking in a health care system* (JAMA)

For general information, here are 4 fact-checked resources:

1. Centers for Disease Controls and Prevention
2. Mayo Clinic
3. The Pathologist
4. The BMJ

How is COVID-19 transmitted? While much is still being learned about this disease, it appears that the main way the virus is spread is through small droplets of moisture that are produced when a person exhales, talks, coughs, or sneezes[5,29]. These tiny droplets can travel many feet through the air and linger in the air or on surfaces for several minutes to hours after the infected person has left the area[12,14,27,30,31]. The virus can enter a new person's body directly by being breathed in or landing in the eyes, nose, or other mucus membranes[32–34]. The virus can also spread indirectly through objects and surfaces.

After infection, most people experience an incubation period where there are no symptoms—typically lasting 5 days, but sometimes lasting 15 days[1,5,35]. Infected individuals are most contagious during the day before first symptoms and in the few days after onset, meaning that people who feel completely healthy can spread the virus to loved ones and strangers[9,29,36]. Up to one in three COVID-19 carriers show no symptoms at all (asymptomatic)[11,37], though they can still spread the virus[1,38]. It is estimated that half of all transmissions occur from individuals not showing symptoms[1,39].

Are masks effective for individuals and communities? There is clear evidence that face coverings reduce the spray of droplets produced during speaking, coughing, and sneezing[12,14,40–43]. This is why masks have long been recommended for individuals with respiratory infections[32,44,45]. Furthermore, home-made cloth masks are similar in effectiveness to surgical masks in diffusing the "jets" of droplets that could spread COVID-19 (for details on mask types, see Figure 1 and the "deep dive")[14]. For example, one of the most definitive studies on viruses and face masks found a 90% reduction in influenza viruses after breathing through a mask and a complete removal of coronaviruses[41]. Because only fitted respirators (the finest-meshed masks) provide reliable protection from external droplets and viral particles[33,44,46], public masking works through "source control,"[6] where "my mask protects you, and your mask protects me."[41]

While it is always difficult to establish cause and effect at the community level, there is now strong evidence that public masking can slow or even stop the spread COVID-19 in states and countries[4,10]. One of the most conclusive studies on the subject compared the effectiveness of universal masking in the health-care system of Massachusetts[7]. This large study involved 75,000 participants,

including healthcare workers and patients. Of all the public health interventions, universal masking appears to be the most associated with stopping the exponential growth of COVID-19 cases, first flattening and then decreasing the infection rate[7]. Another study from Missouri demonstrated the effectiveness of universal masking in commercial settings[8]. Two hair stylists contracted COVID-19 but continued to work for 10 days, servicing 139 clients. Because the salon had a universal masking policy, all stylists and 98% of clients were wearing cloth, surgical, or N95 masks during the encounters. None of the clients or other stylists in the salon developed symptoms[4,8]. Similar accounts are being reported from around the U.S. and the world[4,47–49], supported by quantitative simulations[50].

There is also recent evidence that masking is effective at state and national levels. In countries where public masking was common before the pandemic (where it was culturally normal for sick people to wear masks in public), COVID-19 had an initial daily growth rate of 10%, versus 18% in countries without such norms[9,51,52]. Likewise, the COVID-19 growth rate and mortality rate are lower in countries that required public masking[11,53]. The relationship between public masking and lower COVID-19 mortality could be due to lower viral loading (how many particles you are exposed to) decreasing the severity of infection[53]. This suggests that even when masks do not completely stop transmission, they could still save lives. Universal masking was also pivotal to the success of South Korea and Hong Kong, which were able to contain COVID-19 without lockdowns[6,10,54].

There is very anecdotal evidence that masking may be working in Utah. Since the mask mandate was passed for Salt Lake and Summit Counties on June 27th, the number of new cases in those areas has decreased, while the number of new cases in the rest of the state has increased[55].

Are masks dangerous? Because masks have been used by medical professionals for centuries, there is a large body of scientific evidence about their performance and safety[33,41,46,56–58]. Several mild and rare side effects have been identified, including skin irritation, headaches, and general discomfort in a minority of users[1,15,16,59]. However, certain individuals with acute, preexisting conditions, such as COPD and end-stage renal disease can have difficulty breathing when they wear a respirator (N95) for long periods[18,60–62]. It is also recommended that individuals should not wear a mask if they cannot remove it on their own—for example, children under two, or people who are unconscious—for general comfort and safety reasons[13].

Despite widespread concern on social media and in the news, there is no evidence that masking causes dangerous hypoxia (low oxygen) or hypercapnia (high carbon dioxide) in healthy individuals, even when multiple masks are layered on top of each other[16,59]. In fact, wearing a surgical mask during exercise has been used as a treatment to reduce exercise-induced asthma[58].

There are two main concerns about public masking from a public health perspective, both based on studies of other diseases. **First**, there can be overcompensation or a "false sense of security," where mask users are less vigilant in following other preventative measures such as physical distancing or hand washing[1,52,59]. **Second**, if masks are worn improperly, there can be self-contamination, where bacterial or viral

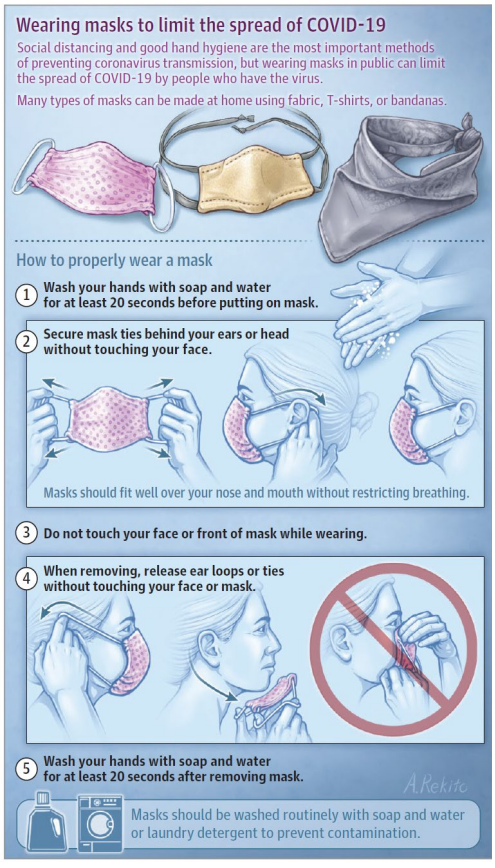

Figure 1. American Medical Association[13]

particles accumulated on the outside of the mask are transferred to the hands and then potentially to the mouth or eyes[33,45,63]. In response to the first concern, observations from this pandemic suggest that wearers of masks are actually more likely to take additional precautions than those who don't wear masks[1,5,10]. To the second point, mask users should wash their hands after removing their mask and wash masks daily (Figure 1). However, the risk of self-contamination is most likely in clinical situations where masks are used to protect the wearers[33,63]. This is less of a concern in a public masking scenario, where masks are used to contain infection sources. Additionally, it has been pointed out that "if a mask is contaminated at removal, it has (by definition) already protected the wearer from contagious droplets."[48]

Perhaps the most robust demonstration of the safety of public masking is that this practice has been widely used for decades in many countries, especially in Asia[51,52,64]. In these regions, where it is common to wear a mask when sick or when there is an outbreak masking has proven safe among children, adults, and the elderly[10,17]. Likewise, widespread use in the northeastern U.S. has been highly safe[4,48]. This history of widespread use decreases the risk of unexpected side-effects[64].

What would the economic consequences be of public masking? The most recent analysis by Goldman Sachs suggests that increasing masking by 25 percentage points from current levels would cut the COVID-19 growth rate by 3-fold and prevent the need for a second round of economic shutdowns[17]. They predict this would result in an economic benefit of approximately $1 trillion. Another study found that 80% of the population wearing cloth masks when in public would be more effective at stopping the virus than a strict lockdown of the whole population[50]. There is nearly universal consensus that masks could be one of the most powerful and cost-effective tools to stop COVID-19 and accelerate the economic recovery[1,4,5,9,10,17].

Deep Dive:

What kinds of masks are we talking about?

There are three main types of masks each with different purposes. Experts have advised the general public to wear cloth face coverings to slow the spread of COVID-19, in conjunction with hand washing, physical distancing, and other protective measures (Figure 1).

N95 Respirator: An N95 mask (formally called a respirator) has an extremely small pore size that filters out most particles and aerosols. Given the shortage of these devices, it has been recommended that N95 masks should be reserved and set aside for healthcare workers in clinical settings. Because they are fitted to the face and have such a high filtration capacity, these respirators provide protection from outside droplets and particles.

Surgical Masks: Surgical masks provide basic protection for the wearer but are primarily meant to protect others from droplets and particles coming from the wearer ("source control"). They are sometimes referred to as 'medical masks.' Some studies show similar performance to N95 respirators for source control[56,63].

Cloth Face Coverings: These are the reusable "home-made" masks that we have been recommended to wear when in public. Surprisingly, they have proven as or more effective as surgical masks and even N95 respirators in some circumstances to contain droplets and disperse air[12,14]. They should be washed and dried daily, and some sources recommend alternating days between masks (Figure 1). The level of filtration theoretically depends on the type of fabric and number of layers[40,43,44]. However, several research groups have pointed out that because the blocking of jets of air and trapping of droplets is the purpose of masks in this pandemic, the most important consideration is comfort, which will increase

likelihood of wearing the mask in different environments and reduce adjustments and touching of the mask[5,9,48].

Because of the unparalleled nature of a pandemic in recent history, it was initially difficult to obtain research on the effectiveness of different mask types in public spaces. However, recent studies have shown decreased cases of COVID-19 in areas where masks and social distancing are mandated, and experts say that the efficacy of these mandates will only increase over time[49].

The most recent studies have shown that even a basic covering is quite effective at limiting the spread of infectious respiratory droplets from speaking or coughing (see Figure 2)[12]. The researchers tracked the number of droplets from the mouth of someone speaking with and without a mask, and their results showed that although cloth coverings certainly aren't foolproof, they prevent most particles from traveling long distances where they could potentially infect others. Other research has also discovered serious differences in filtration of COVID-19 sized droplets between N95, surgical, and cloth masks. This research also found that the most important thing while wearing a mask is to have a proper fit. Even N95 respirators filtered less than 50% of particles when worn with gaps[40].

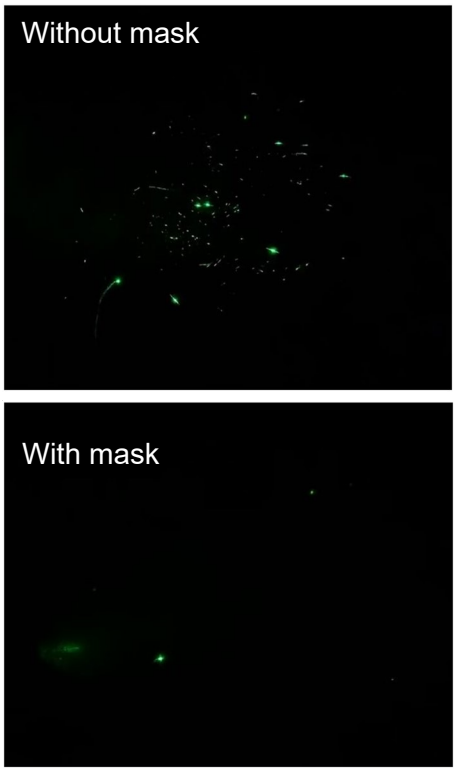

Figure 2. Respiratory droplets ejected into the air while speaking without and with a mask. The images show droplets illuminated with lasers. From Anfinrud and others 2020: Visualizing Speech-Generated Oral Fluid Droplets with Laser Light Scattering.

Face coverings in past pandemics:

Since the late 19th century, facemasks have been used in efforts to prevent the spread of infectious diseases. The first studies began using masks to create a sterile surgical environment. By 1920, surgical masks began to be implemented in many hospitals, although they were slow to catch on because surgeons found them to be annoying and generally preferred to not speak while operating[64]. It wasn't until the 1960s that masks became widespread in hospitals in the United States. Since then, multiple types of research have been conducted to evaluate how much masks can help, including laboratory tests, "natural experiments" where researchers compare effectiveness of different policies, and computer simulations based on what we know about transmission dynamics and the pathology of COVID-19[1,5,64].

During the 1918 influenza pandemic, many western cities (including San Francisco, Phoenix, Seattle, and Juneau) tried to mandate facemasks by law. At that time, most Americans did not understand why they needed to wear masks, and they resisted what they perceived as an unnecessary irritant. "The primary purpose of wearing a mask is not to prevent a healthy person from getting sick, but rather to prevent people already infected from contaminating others through casual contact"[65]. Unfortunately, the 1918 pandemic took the lives of 675,000 Americans, and another 50 million worldwide[66]. As the United States approaches 140,000 deaths from COVID-19, we should consider all the available evidence on this subject, including context from past pandemics.

COVID-19 and Back to School Efforts:

One of the largest decisions facing the country right now is how to safely restart the economy and get children back into school. Thankfully, studies show that children are at a lower risk than adults

when it comes to experiencing severe symptoms from COVID-19. Though much is to be learned about this disease in children, roughly 90% of infected children have been either asymptomatic or had mild symptoms, though infants ages 0 to 1 have shown a greater risk of developing severe or critical symptoms[67–69]. While this is positive news for the health of most children, it could represent a dangerous phenomenon: children who are asymptomatic could serve as unknowing carriers for the disease, potentially infecting their parents, teachers, or other loved ones more at risk. Research into COVID-19 has shown that asymptomatic carriers of the disease have a similar viral load (amount of virus in an organism) as those experiencing severe symptoms[37,38,70–72]. This means that there is a high risk of transmission from asymptomatic carriers[73].

However, evidence from several regions suggests that children are not likely to be "super spreaders" because of low rates of infection and transmission[74] . The biological basis for these differences in children is not clear, though the pattern of low transmission through children appears consistent across all regions with relevant data[75]. As the community discusses this sensitive issue, the effects on student health, community health, and student education and wellbeing should be considered[76]. Coaching children on wearing masks and implementing social distancing may help reduce spread, but as any parent will tell you, even getting children dressed in the morning can be a challenge. In this context, it may be best to focus on carefully educating teachers and administrators about how masks work and providing clear and frequent training on how to help students effectively avoid infection.

In-depth analysis of health risks associated with masking:

Certain health conditions and statuses preclude or increase the risk of wearing face coverings[77]. Young children under the age of 2 should and those who have trouble breathing, due to chronic respiratory conditions or acute or end-stage illness should not wear masks[18,62,78]. Masks are not appropriate for those who are unconscious or otherwise incapable of donning and doffing their own mask. Increased caution should be used when considering masking for individuals with physical, intellectual, or developmental disabilities, such as those of the deaf/hard of hearing community who rely on lip reading to communicate. Lastly, there is little research on the use of masks during exercise, though the World Health Organization recommends against it[58,79–81].

As with all medical interventions, there are several documented side effects of wearing a mask. Face masks can cause discomfort, and wearing a mask can direct exhaled breath into the eyes, leading to general irritation and potentially touching the face, which is a danger to transmission and infection.[59] Wearing a mask in itself can be a reminder to not touch your face, but if they're adjusted or removed frequently, this may negate the protective benefits against transmission and infection[82–84]. One study showed that masks were associated with headaches, vague discomfort, and acne, although the headaches were significantly associated with pre-existing headaches[15].

Some of the main arguments against masks involve fear of hypoxia and hypercapnia—a lower availability of oxygen and an overabundance of carbon dioxide caused by wearing masks. Professionals, cited in media and press publications, and national and international public health organizations concur that it is highly unlikely for either hypoxia or hypercapnia to occur while wearing a mask[6,60,61,78,79,85–87]. The only cases where this has been documented to occur are with the use of N95 respirators by medical patients with acute, preexisting conditions, such as AECOPD and end-stage renal disease[18,60–62]. There are several studies that are widely cited on social media that misinterpret the medical evidence about masks. For example, a small trial of surgical masks among surgeons showed a slight decrease in blood oxygen[88].

The levels stayed within a healthy range and the authors conclude that the deoxygenation may have been due to the stress of performing surgery rather than the masks.[88] Similarly, the studies we cite above about how serious disease can prevent some individuals from safely wearing a mask[18,60–62], are often referenced as evidence for why masks are not safe for healthy individuals. The current literature and industry practices indicate that there is very minimal risk of hypoxia and hypercapnia when wearing N95 respirators, and even when a surgical mask is layered on top there appears to be no physiological burden or significant change in oxygen or carbon dioxide levels[16,48]. There is no evidence that cloth masks, which are looser fit and not sealed, would cause such conditions.

One significant risk of wearing masks lies in overcompensation, also described as the "football-helmet effect." The concept is that the safety provided by a mask can give a false sense of security, leading to greater disregard of other protective measures. For example, cloth masks primarily provide source control rather than external protection ("my mask protects you, your mask protects me"), though some level of external protection appears likely depending on the fabric and way the mask is worn[33,59,82,89]. The fear is that someone wearing a mask might be more likely to engage in risky behaviors and therefore put themselves and others at higher risk of infection[90]. Furthermore, if masks are not worn or cleaned properly, they can result in "self-contamination"[13], as discussed previously. While there is no evidence that masks cause fungal or bacterial infections[86], the more humid habitat created by a mask may allow SARS-CoV-2 to remain active and possibly lead to the defeat of innate immunity and subsequent infection and transmission[59].

In past situations with less virulent diseases and lower levels of community spread, experts expressed caution when extending the successes of mask-wearing to large interpersonal contexts such as schools or healthcare settings[33,45,91]. They emphasized that other preventative measures such as physical distancing, washing hands, and staying home would be more effective than purely relying on masks[92]. In the current pandemic, the consensus is growing that public masking should be used in combination with other efforts rather than not at all[1,5,9,82,89,92]. Even the cautious and consensus-driven World Health Organization, which initially recommended against masks, now encourages their use in areas of widespread COVID-19 transmission[93], in light of new information on the disease and the results of large-scale comparative studies[91].

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