The effectiveness of face masks to prevent SARS-CoV-2 transmission: A summary of literature.

Executive Summary: The Kent County Health Department and Ottawa County Department of Public Health with assistance from the Michigan Department of Health and Human Services, health systems, and other local health departments have compiled scientific articles on the effectiveness of wearing masks during the COVID-19 pandemic. While each individual study may have its own strengths and limitations, the evidence presented in these scientific journal articles taken as a whole demonstrate that masks in healthcare and community settings are effective in reducing the risk of exposure to SARS-CoV-2 and transmission of the virus to others. Epidemiological and modeling studies indicate that communities that established mask mandates generally had reduced disease transmission. Controlled studies examining various masks generally show that masks help prevent the spread of virus-laden droplets. Taken together, current scientific data supports the use of masks to reduce the transmission of COVID-19 in the community.

We will continue to review the science and update our recommendations as needed to protect the health of our community.

Reviews and Meta-analyses:

Chu et al. Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis. Lancet (2020).

> *The authors identified 172 observational coronavirus studies across 16 countries; 38 of these studies specifically studied face masks and the risk of COVID-19 illness. The authors found that the use of either an N95 respirator or face mask (e.g., disposable surgical masks or similar reusable 12–16-layer cotton masks) by those exposed to infected individuals was associated with a large reduction in risk of infection (up to an 85% reduced risk). The use of face masks was protective for both health-care workers and people in the community exposed to infection.*

MacIntyre et al. A rapid systematic review of the efficacy of face masks and respirators against coronaviruses and other respiratory transmissible viruses for the community, healthcare workers and sick patients. International Journal of Nursing Studies (2020).

> *The authors describe 8 clinical trials evaluating the effectiveness of face masks to reduce respiratory viruses and SARS CoV2 transmission. Their analysis suggests that community mask use by well people could be beneficial, particularly for COVID-19, where transmission may be pre-symptomatic. The studies of masks as source control (where sick persons use masks to reduce spread) also suggest a benefit and may be important during the COVID-19 pandemic in both community and health care settings.*

Wang J, Pan L, Tang S, Ji JS, Shi X. Mask use during COVID-19: A risk adjusted strategy. *Environ Pollut*. (2020). 266(Pt 1):115099.

> *Prior to COVID-19, the authors highlight a large systematic review from 67 studies that showed that wearing masks is one of the important barriers to controlling respiratory viruses transmission; and evidences indicates that N95 respirators were similarly effective to surgical masks (Jefferson et al., 2011). Additionally, the authors summarized that the main transmission routes of SARS CoV-2 include droplet, contact transmissions, and airborne transmissions, which is characterized by high proportion of cases with mild symptom or asymptomatic cases, and the necessity of wearing masks by the public during COVID-19 pandemic has been under-emphasized.*

Brainard et al. Facemasks and similar barriers to prevent respiratory illness such as COVID-19: A rapid systematic review. medRxiv (2020).

The authors reviewed 31 clinical trials and observational studies to better understand the value of wearing facemasks in community settings to prevent respiratory illness. The authors report that when both housemates and an infected household member wore facemasks the likelihood of additional household members becoming ill may be modestly reduced by around 19%. The authors go on to conclude that, based on clinical trials, wearing facemasks can be slightly protective against primary infection from casual community contact, and modestly protective against household infections when both infected and uninfected members wear facemasks.

Gandhi et al. Masks Do More Than Protect Others During COVID-19: Reducing the Inoculum of SARS-CoV-2 to Protect the Wearer. J Gen Intern Med (2020);1-4.

The authors suggest that although universal public masking can certainly protect others, the "inoculum" theory (the amount of virus particles one could be exposed to) argues for a major protective effect for the individual. Masks, depending on the material and design, filter out a majority of viral particles and decrease the overall 'dose' of virus particles one could be exposed to. This perspective commentary puts forth another advantage of population-level facial masking for pandemic control with SARS-CoV-2 based on an old but enduring theory regarding viral inoculum.

Howard et al. Face Masks Against COVID-19: An Evidence Review. Proceedings National Academy Sciences (2020).

This review of the literature offers evidence in favor of widespread mask use to reduce community transmission: masks use materials that obstruct droplets of the necessary size; people are most infectious in the initial period post-infection masks have been effective in reducing transmission of influenza; non-medical masks have been shown to be effective at blocking transmission of coronavirus; and places and time periods where mask usage is required or widespread have shown substantially lower community transmission. The available evidence suggests that near-universal adoption of non-medical masks when out in public, in combination with complementary public health measures could successfully reduce effective-R to below 1.0, thereby stopping community spread.

Matuschek et al. Face masks: benefits and risks during the COVID-19 crisis. Eur J Med Res. 2020 Aug 12;25(1):32.

In this review of the available literature, the authors found that the use of masks that include mouth and nose covering were linked to relevant protection during close contact scenarios by limiting pathogen-containing aerosol and liquid droplet dissemination. Wearing a mask in areas where sufficient distance is not feasible, such as public transportation, most likely reduces the spread of virus-loaded droplets and therefore the risk of transferring SARS-CoV-2. However, the authors note that if masks are not exchanged regularly (or washed properly when made of cloth), pathogens can accumulate in the mask. When improperly used, the risk of spreading the pathogen—including SARS-CoV-2—might be critically increased.

Brooks JT, Butler JC. Effectiveness of Mask Wearing to Control Community Spread of SARS-CoV-2. JAMA. 2021;325(10):998–999.

The authors review the data that demonstrate that community mask wearing is an effective nonpharmacologic intervention to reduce the spread of this infection, especially as source control to prevent spread from infected persons, but also as protection to reduce wearers' exposure to infection. The authors conclude that with the emergence of more transmissible SARS-CoV-2 variants, it is even more important to adopt widespread mask wearing as well as to redouble efforts with use of all other nonpharmaceutical prevention measures until effective levels of vaccination are achieved nationally.

Prather KA, Wang CC, Schooley RT. Reducing transmission of SARS-CoV-2. Science. 2020 Jun 26;368(6498):1422-1424.

The authors review the evidence around transmission of SARS-CoV-2 and interventions to reduce its spread. They conclude that places that have been most effective in reducing the spread of COVID-19 have implemented universal masking and suggest that for society to resume, measures designed to reduce aerosol transmission must be implemented, including universal masking and regular, widespread testing to identify and isolate infected asymptomatic individuals.

Liang, M et al. Efficacy of face mask in preventing respiratory virus transmission: A systematic review and meta-analysis. Travel Med Infect Dis. 2020 July-August; 36: 101751

The authors review 21 studies and conclude that the use of masks by healthcare workers (HCWs) and non-healthcare workers (Non-HCWs) can reduce the risk of respiratory virus infection by 80%. This study adds additional evidence of the enhanced protective value of masks, and the authors stress that the use masks serve as an adjunctive method regarding the COVID-19 outbreak.

Abboah-Offei, M et al. A rapid review of the use of face mask in preventing the spread of COVID-19, International Journal of Nursing Studies Advances, Volume 3, 2021

The authors review 58 studies and conclude that regardless of the type, setting, or who wears the face mask, it serves primarily a dual preventive purpose; protecting oneself from getting viral infection and protecting others. Therefore, if everyone wears a face mask in public, it offers a double barrier against COVID-19 transmission.

Coclite, D et al. Face Mask Use in the Community for Reducing the Spread of COVID-19: A Systematic Review. Front Med (Lausanne) 2020; 7: 594269.

The authors review 35 studies, including three randomized controlled trials, 10 comparative studies, 13 predictive models, and nine laboratory experimental studies. The findings of this systematic review and meta-analysis support the use of face masks in a community setting but robust randomized trials on face mask effectiveness are needed to inform evidence-based policies.

Yuxin Wang, Zicheng Deng, Donglu Shi; How effective is a mask in preventing COVID-19 infection? Medical Devices and Sensors, 20 December 2020

The authors review the evidence on COVID-19 transmission and the functions of masks in a respiratory epidemic. Based on the information reviewed, the recommended social distancing range of 1–2 m (CDC, 2020; WHO, 2020) may not necessarily guarantee the epidemic prevention. The authors conclude that wearing mask in public is essential as its effectiveness has been well established by the current studies. Based on the current studies: correctly wearing masks of all kinds, despite their different designs, functions and effectiveness, will to a large degree reduce the overall risks of COVID-19 infection and enhance general protection from coronavirus.

Greenhalgh, T et al.; Face masks for the public during the covid-19 crisis. BMJ 2020; 369

The authors conclude that, in the face of a pandemic the search for perfect evidence may be the enemy of good policy. As with parachutes for jumping out of airplanes, it is time to act without waiting for randomized controlled trial evidence. Masks are simple, cheap, and potentially effective. Worn both in the home (particularly by the person showing symptoms) and also outside the home in situations where meeting others is likely (for example, shopping, public transport), they could have a substantial impact on transmission with a relatively small impact on social and economic life.

Anthony Paulo Sunjaya, Christine Jenkins; Rationale for universal face masks in public against COVID-19. Respirology. 2020 Apr 30

This paper reviews the available evidence surrounding COVID-19 transmission and mitigation methods. The theoretical rationale discussed in the article suggests that along with evidence-based recommendations such as physical distancing and maintaining hand hygiene, universal masking may help in reducing droplet-based transmission of COVID and contribute to flattening and shortening the curve.

Catherine M. Clase, et al; Cloth Masks May Prevent Transmission of COVID-19: An Evidence-Based, Risk-Based Approach*. Annals of Internal Medicine, 15 September 2020Volume 173, Issue 6: 489-491*

The study reviews the available evidence and indicates that while the researchers don't have enough data to rule that cloth masks stop transmission of respiratory droplets from coming in through a mask, there's "convincing" evidence to say that cloth masks do reduce particles from going out of a mask and contaminating air and surfaces. The researchers explain: "Every virus-laden particle retained in a mask is not available to hang in the air as an aerosol or fall to a surface to be later picked up by touch."

C Raina MacIntyre and S Jay Hasanain; Community universal face mask use during the COVID 19 pandemic—from households to travellers and public spaces*, Journal of Travel Medicine, Volume 27, Issue 3, April 2020*

This paper reviews the existing evidence. The paper shows that data from several community RCTs and experimental studies support universal face mask use (UFMU) in community settings where there is a high incidence of COVID-19,4 both inside households and closed venues, in crowded public spaces and public transport, and for travellers passing through airports and spending time on airplanes. If epidemic control is poor, until an effective vaccine is available, UFMU may contribute to reducing transmission, preventing deaths and flattening the curve.

Epidemiologic Studies:

Stutt et al. A modelling framework to assess the likely effectiveness of facemasks in combination with 'lock-down' in managing the COVID-19 pandemic. Proc. R. Soc.

The authors use two complementary mathematical modelling approaches to test the effectiveness of facemask wearing by sections of the population in reducing the transmission rate of SARS-Cov-2. Their models show that, when facemasks are used by the public all the time (not just from when symptoms first appear), the effective reproduction number can be decreased below 1, leading to the overall reduction of disease spread.

Mitze et al. Face Masks Considerably Reduce COVID-19 Cases in Germany: A Synthetic Control Method Approach. Institute of Labor Economics (2020).

> *The authors assessed the impact of mandatory face mask policies in Germany on national case counts reported to federal health authorities. Depending on the region they analyzed, the authors found that face masks reduced the cumulative number of reported COVID-19 cases between 2.3% and 13% over a period of 10 days after they became compulsory. The authors go on to conclude that the introduction of face masks on 6 April reduced the number of new infections over the next 20 days by almost 25%.*

Rader B et al. Mask Wearing and Control of SARS-CoV-2 Transmission in the United States. medRxiv (2020).

> *The authors conducted cross-sectional surveys and used a multivariate logistic model to predict community transmission using state- and week-specific estimates for mask wearing. The authors, controlling for social distancing and other variables, found that a 10% increase in mask wearing was associated with a 3.5-fold increased likelihood of controlling disease transmission. Specifically, communities with high mask wearing adherence and social distancing have the highest predicted probability of a controlled epidemic.*

Zhang et al. Identifying airborne transmission as the dominant route for the spread of COVID-19. Proceedings of the National Academy of Sciences (2020), 117 (26) 14857-4863.

> *The authors quantified the impact of face coverings by projecting the number of new infections based on the data prior to implementing the use of face masks in Italy on April 6 and NYC on April 17. Their analysis indicated that face coverings reduced the number of infections by over 75,000 in Italy from April 6 to May 9 and by over 66,000 in NYC from April 17 to May 9. The authors concluded that wearing of face masks in public corresponds to the most effective means to prevent interhuman transmission, and this inexpensive practice, in conjunction with extensive testing, quarantine, and contact tracing, poses the most probable opportunity to stop the COVID-19 pandemic, prior to the development of a vaccine.*

Wang et al. Reduction of secondary transmission of SARS-CoV-2 in households by face mask use, disinfection and social distancing: a cohort study in Beijing, China. BMJ Glob Health (2020).

> *In this retrospective cohort study, the authors analyzed factors that prevented secondary transmission of COVID-19 among household contacts. The authors found that face mask use by the primary case and family contacts before the primary case developed symptoms was 79% effective in reducing secondary transmission.*

Sims MD, et al. Coronavirus Disease 2019 (COVID-19) Seropositivity and Asymptomatic Rates in Healthcare Workers Are Associated with Job Function and Masking, Clinical Infectious Diseases, Volume 73, Issue Supplement_2, 1 August 2021, Pages S154–S162

> *This study involved an online assessment that included demographic, clinical, and exposure information and a blood sample was collected from 20 614 employees at Beaumont Health in southeast Michigan. A total of 1818 (8.8%) participants were seropositive between April 13 and May 28, 2020. Among the seropositive individuals, 44% reported that they were asymptomatic during the month prior to blood collection. Among participants reporting direct exposure to a Coronavirus Disease 2019 (COVID-19) positive individual, those wearing an N95/PAPR mask had a significantly lower seropositivity rate (10.2%) compared to surgical/other masks (13.1%) or no mask (17.5%).*

Doung-ngern et al. Case-control study of use of personal protective measures and risk for SARS-CoV-2

infection, Thailand. Emerg Infect Dis (2020).

> *In this case-control study in Thailand of 211 cases and 839 controls, the authors found that wearing masks all the time during contact was independently associated with a 77% reduced risk of SARS-CoV-2 infection compared with not wearing masks. The authors also found the type of mask worn was not independently associated with infection.*

Wilson et al. Factors Influencing Risk for COVID-19 Exposure Among Young Adults Aged 18–23 Years — Winnebago County, Wisconsin, March–July 2020. MMWR Morb Mortal Wkly Rep (2020); 69:1497–1502.

> *During an outbreak of COVID-19 among young adults in Wisconsin, the authors conducted 30 key informant interviews. Most interviewees reported exposure to misinformation, conflicting messages, or opposing views about the need for and effectiveness of masks. The authors concluded that exposure to misinformation and unclear messages may have been a driver of the outbreak, underscoring the importance of providing clear and consistent messages about the need for and effectiveness of masks.*

Leffler et al. Association of country-wide coronavirus mortality with demographics, testing, lockdowns, and public wearing of masks. Am J Trop Med Hyg. 2020 Dec;103(6):2400-2411.

> *The authors analyzed differences between countries to determine sources of variation in per-capita mortality from COVID-19. In countries with cultural norms or government policies supporting public mask-wearing, per-capita coronavirus mortality increased on average by just 15.8% each week, as compared with 62.1% each week in remaining countries. The authors concluded that societal norms and government policies supporting the wearing of masks by the public, as well as international travel controls, are independently associated with lower per-capita mortality from COVID-19.*

Lyu et al. Community Use of Face Masks And COVID-19: Evidence From A Natural Experiment Of State Mandates In The US. Health Affairs (2020).

> *This study, similar to Leffler et al, compares government mandates for face mask use in public issued by fifteen states during April 8 and May 15, 2020. The authors concluded that mandating face mask use in public was associated with a decline in the daily COVID-19 growth rate by 0.9, 1.1, 1.4, 1.7, and 2.0 percentage points in 1–5, 6–10, 11–15, 16–20, and 21 or more days after state face mask orders were signed, respectively. Estimates suggest that as a result of the implementation of these mandates, more than 200,000 COVID-19 cases were averted by May 22, 2020. The findings suggested that requiring face mask use in public could help in mitigating the spread of COVID-19.*

Eikenberry et al. To mask or not to mask: Modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic. Infect Dis Model (2020);5:293-308.

> *The authors use a mathematical model to simulate the impact of universal mask wearing. Hypothetical mask adoption scenarios, for Washington and New York state, suggest that immediate near universal (80%) adoption of moderately (50%) effective masks could prevent on the order of 17-45% of projected deaths over two months in New York, while decreasing the peak daily death rate by 34-58%, absent other changes in epidemic dynamics. In Washington, where baseline transmission is much less intense, 80% adoption of such masks could reduce mortality by 24–65% (and peak deaths 15–69%), compared to 2–9% mortality reduction in New York (peak death reduction 9–18%).*

Hendrix MJ, Walde C, Findley K, Trotman R. Absence of Apparent Transmission of SARS-CoV-2 from Two Stylists After Exposure at a Hair Salon with a Universal Face Covering Policy — Springfield, Missouri, May 2020. MMWR Morb Mortal Wkly Rep 2020;69:930-932.

Among 139 clients exposed to two symptomatic hair stylists with confirmed COVID-19 while both the stylists and the clients wore face masks, no symptomatic secondary cases were reported; among 67 clients tested for SARS-CoV-2, all test results were negative. Adherence to the community's and company's face-covering policy likely mitigated spread of SARS-CoV-2.

Guy GP Jr., Lee FC, Sunshine G, et al. Association of State-Issued Mask Mandates and Allowing On-Premises Restaurant Dining with County-Level COVID-19 Case and Death Growth Rates — United States, March 1–December 31, 2020. MMWR Morb Mortal Wkly Rep 2021;70:350–354.

County-level data on state-issued mask mandates and restaurant closures were obtained from executive and administrative orders identified on state government websites. Two outcomes were examined: the daily percentage point growth rate of county-level COVID-19 cases and county-level COVID-19 deaths. Mandating masks was associated with a decrease in daily COVID-19 case and death growth rates within 20 days of implementation.

Van Dyke ME, Rogers TM, Pevzner E, et al. Trends in County-Level COVID-19 Incidence in Counties With and Without a Mask Mandate — Kansas, June 1–August 23, 2020. MMWR Morb Mortal Wkly Rep 2020;69:1777-1781

Daily county-level COVID-19 incidence (cases per 100,000 population) was calculated using case and population counts accessed from USAFacts for Kansas counties during June 1–August 23. Rates were calculated as 7-day rolling averages. Mandated and nonmandated counties were compared to themselves over time, allowing for the control of constant county-related characteristics (e.g., urbanicity or rurality) that might otherwise confound a comparison between mandated and nonmandated counties. Countywide mask mandates appear to have contributed to the mitigation of COVID-19 transmission in mandated counties. Community-level mitigation strategies emphasizing use of masks, physical distancing, staying at home when ill, and enhanced hygiene practices can help reduce the transmission of SARS-CoV-2.

Lessler, J et al. Household COVID-19 risk and in-person schooling SCIENCE 04 JUN 2021 : 1092-1097

Data from a massive online survey in the United States indicate an increased risk of COVID-19–related outcomes among respondents living with a child attending school in person. School-based mitigation measures are associated with significant reductions in risk, particularly daily symptoms screens, teacher masking, and closure of extracurricular activities. Although in-person schooling is associated with household COVID-19 risk, this risk can likely be controlled with properly implemented school-based mitigation measures.

Payne DC, Smith-Jeffcoat SE, Nowak G, et al; CDC COVID-19 Surge Laboratory Group. SARS-CoV-2 infections and serologic responses from a sample of U.S. Navy Service Members: USS Theodore Roosevelt, April 2020. MMWR Morb Mortal Wkly Rep. 2020;69(23):714-721.

In April, the U.S. Navy and CDC investigated a COVID-19 outbreak aboard the USS Theodore Roosevelt among a convenience sample of 382 service members. The outbreak was characterized by widespread transmission with relatively mild symptoms and asymptomatic infection among this sample of mostly young, healthy adults with close, congregate exposures. Service members who reported taking preventive measures had a lower infection rate than did those who did not report taking these measures (e.g., wearing a face covering, 55.8% versus 80.8%).

Schwartz, K; Lack of COVID-19 transmission on an international flight. *CMAJ April 14, 2020 192 (15) E410*

> *This study investigated transmission after a patient was symptomatic with dry cough during a flight from China to Canada. None of the 25 passengers considered "close contacts" aboard the flight contracted the virus. Transmission may have been mitigated by mild symptoms and masking during the flight.This study indicated that droplet transmission was likely more prevalent than airborne transmission.*

Hershow RB, Wu K, Lewis NM, et al. Low SARS-CoV-2 Transmission in Elementary Schools — Salt Lake County, Utah, December 3, 2020–January 31, 2021. MMWR Morb Mortal Wkly Rep 2021;70:442–448

> *In this investigation, COVID testing was offered to 735 school contacts of 51 index patients across 20 elementary schools in communities with high COVID-19 transmission. Five positive cases were identified for a secondary attack rate of 0.7%. Adherence to mask use was high among the schools included, but students' classroom seats were <6 ft apart and a median of 3 ft apart.*

Dawson P, Worrell MC, Malone S, et al. Pilot Investigation of SARS-CoV-2 Secondary Transmission in Kindergarten Through Grade 12 Schools Implementing Mitigation Strategies — St. Louis County and City of Springfield, Missouri, December 2020. MMWR Morb Mortal Wkly Rep 2021;70:449–455

> *In 22 participating K–12 schools implementing multiple COVID-19 mitigation strategies, school-based SARS-CoV-2 secondary transmission was detected in two of 102 tested close contacts of 37 persons with COVID-19. Schools implementing strategies including mask mandates, physical distancing, and increased ventilation had much lower SARS-CoV-2 transmission than in the community.*

Gold JA, Gettings JR, Kimball A, et al. Clusters of SARS-CoV-2 Infection Among Elementary School Educators and Students in One School District — Georgia, December 2020–January 2021. MMWR Morb Mortal Wkly Rep 2021;70:289–292

> *Among nine clusters of SARS-CoV-2 transmission in a Georgia school district during December 1, 2020–January 22, 2021, it was found that five of the clusters involved inadequate mask use by students.*

Modeling Studies:

Victor Chernozhukov, Hiroyuki Kasahara, Paul Schrimpf, Causal impact of masks, policies, behavior on early covid-19 pandemic in the U.S.*., Journal of Econometrics, Volume 220, Issue 1, 2021, Pages 23-62*

> *This paper quantitatively assesses the impact of various policies adopted by US states on the spread of Covid-19, such as non-essential business closure and mandatory face masks, paying particular attention to how people adjust their behavior in response to policies as well as new information on cases and deaths. The analysis concluded that if the US had on 1 April 2020 universally mandated that employees of public-facing businesses use masks, there could have been nearly 40% fewer deaths by the start of June.*

Cheng, Y et al. Face masks effectively limit the probability of SARS-CoV-2 transmission*. Science 25 Jun 2021 : 1439-1443*

> *In this work, the authors develop a quantitative model of airborne virus exposure and provide a basis for quantifying the efficacy of face masks. They show that mask efficacy strongly depends on airborne virus abundance. On the basis of direct measurements of SARS-CoV-2 in air samples and population-level infection probabilities, they find that the virus abundance in most environments is sufficiently low for masks to be effective in reducing airborne transmission.*

IHME COVID-19 Forecasting Team. Modeling COVID-19 scenarios for the United States. *Nat Med 27, 94–105 (2021)*

> *The study finds that achieving universal mask use (95% mask use in public) could be sufficient to ameliorate the worst effects of epidemic resurgences in many states. Universal mask use could save an additional 129,574 (85,284–170,867) lives from September 22, 2020 through the end of February 2021, or an additional 95,814 (60,731–133,077) lives assuming a lesser adoption of mask wearing (85%), when compared to the reference scenario.*

Shen, M., Zu, J., Fairley, C.K. et al. Effects of New York's Executive Order on Face Mask Use on COVID-19 Infections and Mortality: A Modeling Study. J Urban Health 98, 197–204 (2021)

> *Modeling results showed that the executive order on face mask use was estimated to avert 99,517 (95% CIs 72,723–126,312) COVID-19 infections and 7978 (5692–10,265) deaths in NYC. If the executive order was implemented 1 week earlier (on April 10), the averted infections and deaths would be 111,475 (81,593–141,356) and 9017 (6446–11,589), respectively. If the executive order was implemented 2 weeks earlier (on April 3 when the Centers for Disease Control and Prevention recommended face mask use), the averted infections and deaths would be 128,598 (94,373–162,824) and 10,515 (7540–13,489), respectively.*

Stuart RM, Abeysuriya RG, Kerr CC, et al; Role of masks, testing and contact tracing in preventing COVID-19 resurgences: a case study from New South Wales, Australia. BMJ Open 2021;11

> *The study finds that the relative impact of masks is greatest when testing and tracing rates are lower and vice versa. Our work suggests that testing, tracing and masks can all be effective means of controlling transmission. A multifaceted strategy that combines all three, alongside continued hygiene and distancing protocols, is likely to be the most robust means of controlling transmission of SARS-CoV-2.*

Worby, C.J., Chang, HH. Face mask use in the general population and optimal resource allocation during the COVID-19 pandemic. Nat Commun 11, 4049 (2020)

> *The models explored in this study found: 1) Even limited distribution of masks offering only 25% protection and containment would result in significant drop in death rates, 2) Even if only 10% of people used the masks offering 25% protection, the death rate would drop 5%, 3) If people used homemade masks that offered even 5% protection and containment, death rates would drop from 2.5 to 2.26 percentage points. Places requiring public masking could also expect a 3-5% reduction in deaths.*

Scott N, Saul A, Spelman T, Stoove M, Pedrana A, Saeri A, et al. (2021) The introduction of a mandatory mask policy was associated with significantly reduced COVID-19 cases in a major metropolitan city. PLoS ONE 16(7)

> *This study estimated exponential epidemic growth or decay rates in daily COVID-19 diagnoses using a non-weighted linear regression of the natural logarithm of the daily cases against time. The mandatory mask use policy substantially increased public use of masks and was associated with a significant decline in new COVID-19 cases after introduction of the policy. This study strongly supports the use of masks for controlling epidemics in the broader community.*

Rao IJ, Vallon JJ, Brandeau ML. Effectiveness of Face Masks in Reducing the Spread of COVID-19: A Model-Based Analysis. Med Decis Making. 2021 May 27

> *Authors developed a dynamic disease model to assess the effectiveness of face masks in reducing the spread of COVID-19, during an initial outbreak and a later resurgence, as a function of mask effectiveness, coverage, intervention timing, and time horizon. The model found that even moderately effective face masks can play a role in reducing the spread of COVID-19, particularly with full coverage, but should be combined with social distancing measures to reduce Re below 1.*

Kai, D, et al; Universal Masking is Urgent in the COVID-19 Pandemic: SEIR and Agent Based Models, Empirical Validation, Policy Recommendations, Cornell University

> *The authors present two models for the COVID-19 pandemic predicting the impact of universal face mask wearing. Taken in tandem, our theoretical models and empirical results argue for urgent implementation of universal masking in regions that have not yet adopted it as policy or as a broad cultural norm.*

Siddhartha Verma, Manhar Dhanak, and John Frankenfield; Visualizing the effectiveness of face masks in obstructing respiratory jets, Physics of Fluids 32, 061708 (2020)

> *The authors use qualitative visualizations of emulated coughs and sneezes to examine how material- and design-choices impact the extent to which droplet-laden respiratory jets are blocked. In addition to providing an initial indication of the effectiveness of protective equipment, the visuals used in this study can help convey to the general public the rationale behind social-distancing guidelines and recommendations for using face masks. Promoting widespread awareness of effective preventative measures is crucial, given the high likelihood of a resurgence of COVID-19 infections in the fall and winter.*

Bourouiba L. Turbulent Gas Clouds and Respiratory Pathogen Emissions: Potential Implications for Reducing Transmission of COVID-19. JAMA. 2020;323(18):1837–1838

> *This study investigates how turbulent gas cloud dynamics should influence the design and recommended use of surgical and other masks. These masks can be used both for source control (ie, reducing spread from an infected person) and for protection of the wearer (ie, preventing spread to an unaffected person). Mask efficacy as source control depends on the ability of the mask to trap or alter the high-momentum gas cloud emission with its pathogenic payload. Peak exhalation speeds can reach up to 33 to 100 feet per second (10-30 m/s), creating a cloud that can span approximately 23 to 27 feet (7-8 m). Protective and source control masks, as well as other protective equipment, should have the ability to repeatedly withstand the kind of high-momentum multiphase turbulent gas cloud that may be ejected during a sneeze or a cough and the exposure from them.*

Martin Z. Bazant and John W. M. Bush; A guideline to limit indoor airborne transmission of COVID-19. PNAS April 27, 2021 118 (17)

> This simulation looking into indoor airborne transmission of COVID-19 investigated how long it would take for there to be a >50% chance of transmission occurring If 1 infectious child attends a class of 25 students. Complete masking increased the time from 3 hours to 120 hours among elementary school children and 2 hours to 89 hours among high school students.

Zhang Y, et al. COVID-19 Projections for K12 Schools in Fall 2021: Significant Transmission without Interventions. medRxiv, August 2021

> *The authors used an extended Susceptible-Infected-Recovered computational model to estimate the number of new infections during 1 semester among a student population under different assumptions about mask usage, routine testing, and levels of incoming protection. Results indicated that universal masking can reduce student infections by 26-78%, and biweekly testing along with masking reduces infections by another 50%. To prevent new infections in the community, limit school absences, and maintain in-person learning, interventions such as masking and testing must be implemented widely, especially among elementary school settings in which children are not yet eligible for the vaccine.*

Controlled Experiments:

Ma QX, Shan H, Zhang HL, Li GM, Yang RM, Chen JM. Potential utilities of mask-wearing and instant hand hygiene for fighting SARS-CoV-2. *J Med Virol* (2020).

> *In this study, the efficacy of three types of masks were evaluated using the avian influenza virus to simulate the coronavirus. N95 masks, medical masks, and homemade masks made of four-layer kitchen paper and one-layer cloth could block 99.98%, 97.14%, and 95.15% of the virus in*

aerosols. With these data, the authors propose the approach of mask-wearing to slow the exponential spread of the virus.

Leung, N.H.L., Chu, D.K.W., Shiu, E.Y.C. *et al.* Respiratory virus shedding in exhaled breath and efficacy of face masks. *Nat Med* **26,** 676–680 (2020).

The authors tested viral shedding (in terms of viral copies per sample) in nasal swabs, throat swabs, respiratory droplet samples and aerosol samples and compared the latter two between samples collected with or without a face mask. The study demonstrated the efficacy of surgical masks to reduce coronavirus detection and viral copies in large respiratory droplets and in aerosols.

Fischer et al. Low-cost measurement of face mask efficacy for filtering expelled droplets during speech. Science Advances (2020).

The authors demonstrated a simple optical measurement to evaluate the efficacy of masks to reduce the transmission of respiratory droplets during regular speech. In their proof-of-concept study, they compared a variety of commonly available mask types and observed that some mask types such as clothe masks approach the performance of standard surgical masks, while some mask alternatives, such as neck gaiters or bandanas, offer very little protection.

Bae et al. Effectiveness of Surgical and Cotton Masks in Blocking SARS–CoV-2: A Controlled Comparison in 4 Patients. Annal of Internal Medicine (2020).

In this study of only 4 patients, the authors compared disposable surgical masks with reusable 100% cotton masks to filter SARS CoV-2. Neither surgical nor cotton masks effectively filtered SARS–CoV-2 during coughs by infected patients.

Konda A, Prakash A, Moss GA, Schmoldt M, Grant GD, Guha S. Aerosol Filtration Efficiency of Common Fabrics Used in Respiratory Cloth Masks. ACS Nano (2020)14(5):6339-6347.

This study assessed filtration effectiveness of various mask materials. Although the filtration efficiencies for various fabrics when a single layer was used ranged from 5 to 80% and 5 to 95% for particle sizes of <300 nm and >300 nm, respectively, the efficiencies improved when multiple layers were used and when using a specific combination of different fabrics. Filtration efficiencies of the hybrids (such as cotton-silk, cotton-chiffon, cotton-flannel) was >80% (for particles <300 nm) and >90% (for particles >300 nm). Cotton, the most widely used material for cloth masks performs better at higher weave densities (i.e., thread count) and can make a significant difference in filtration efficiencies.

*Chan JF, et al.*Surgical Mask Partition Reduces the Risk of Noncontact Transmission in a Golden Syrian Hamster Model for Coronavirus Disease 2019 (COVID-19)*. Clin Infect Dis. 2020 Nov 19;71(16):2139-2149.*

Noncontact transmission was found in 66.7% (10/15) of exposed naive hamsters. Surgical mask partition for challenged index or naive hamsters significantly reduced transmission to 25% (6/24, P = .018). Surgical mask partition for challenged index hamsters significantly reduced transmission to only 16.7% (2/12, P = .019) of exposed naive hamsters.

Kähler CJ, Hain R. Fundamental protective mechanisms of face masks against droplet infections. J

Aerosol Sci. 2020 Oct;148:105617. doi: 10.1016/j.jaerosci.2020.105617.

The authors conducted two sets of experiments. In the first sets of the experiments, the flow field generated by coughing without and with a surgical mask was examined as coughing sets the air strongly in motion and because coughing is a typical symptom of COVID-19. In the second set of experiments, common household materials currently used by the population to make simple masks at home were tested and a surgical mask were tested to visualize their filtering properties. Based on their findings, the authors stated that wearing simple homemade or surgical face masks in public is highly recommended if no particle filtrating respiratory mask is available. Firstly, because they protect against habitual contact of the face with the hands and thus serve as self-protection against contact infection. Secondly, because the flow resistance of the masks ensures that the air remains close to the head when breathing, speaking, singing, coughing and sneezing, thus protecting other people if they have sufficient distance from each other.

Ruba AL, Pollak SD. Children's emotion inferences from masked faces: Implications for social interactions during COVID-19. PLoS One. 2020 Dec 23;15(12)

The study recruited a racially diverse sample of school-aged (7- to 13-years) children from publicly funded after-school programs. Children made inferences from facial configurations that were not covered, wearing sunglasses to occlude the eyes, or wearing surgical masks to occlude the mouth. Children were still able to make accurate inferences about emotions, even when parts of the faces were covered.

Anfinrud P, Stadnytskyi V, Bax CE, Bax A. Visualizing speech-generated oral fluid droplets with laser light scattering. N Engl J Med 2020;382:2061-2062.

The study used a laser to produce flashes as fluid droplets entered the air while a subject was speaking. When observed, between 227 and 347 oral fluid droplets flashed when participants said the words "stay healthy" without a mask. When the same phrase was spoken with a mask, "the flash count remained close to background level.

Onur Aydin,O, et al. Performance of fabrics for home-made masks against the spread of COVID-19 through droplets: A quantitative mechanistic study, Extreme Mechanics Letters, Volume 40, 2020

The study found that cloth face coverings, particularly masks with multiple layers, have over 70% blocking efficiency. Multiple-layered fabric was found to stop droplets with more than 94% efficiency, which is equitable to that of medical masks.

Clapp PW, Sickbert-Bennett EE, Samet JM, et al. Evaluation of Cloth Masks and Modified Procedure Masks as Personal Protective Equipment for the Public During the COVID-19 Pandemic. JAMA Intern Med. 2021;181(4):463–469

The objective of this study was to evaluate the fitted filtration efficiency (FFE) of various consumer-grade and improvised face masks, as well as several popular modifications of medical procedure masks that are intended to improve mask fit or comfort. Simple modifications can improve the fit and filtration efficiency of medical procedure masks; however, the practical effectiveness of consumer-grade masks available to the public is, in many cases, comparable with or better than their non-N95 respirator medical mask counterparts.

Jonathan R. Tomshine JR et al. Combined Effects of Masking and Distance on Aerosol Exposure Potential*, Mayo Clinic Proceedings, Volume 96, Issue 7, 2021, Pages 1792-1800*

The objective of this study was to quantify the efficacy of masking and "social distancing" on the transmission of airborne particles from a phantom aerosol source (simulating an infected individual) to a nearby target (simulating a healthy bystander) in a well-controlled setting.Compared with a baseline of 1-foot separation with no masks employed, particle count was reduced by 84% at 3 feet of separation and 97% at 6 feet. A modest decrease in particle

count was observed when only the receiver was masked. The most substantial exposure reduction occurred when the aerosol source was masked (or both parties were masked). When both the source and target were masked, particle count was reduced by more than 99.5% of baseline, regardless of separation distance or which type of mask was employed.