The Case for Universal Cloth Mask Adoption & Policies to Increase the Supply of Medical Masks for Health Workers
April 1 2020

Jason Abaluck, PhD. Associate Professor of Economics, Yale School of Management
Judith Chevalier, PhD. William S Beinecke Professor of Economics and Finance, Yale School of Management
Nicholas A. Christakis, MD., PhD., MPH. Sterling Professor of Social and Natural Science, Department of Sociology, Department of Statistics and Data Science, Department of Ecology and Evolutionary Biology, Department of Biomedical Engineering, Department of Medicine, Yale University.
Howard Forman, MD, MBA. Professor of Radiology and Biomedical Imaging, Economics, and Public Health (Health Policy); Professor in the Practice of Management, Yale School of Management.
Edward H. Kaplan, PhD. William N. and Marie A. Beach Professor of Operations Research, Yale School of Management; Professor of Public Health, Yale School of Public Health; Professor of Engineering, Yale University.
Albert Ko, MD. Professor of Epidemiology and Medicine and Department Chair, Epidemiology of Microbial Diseases, Yale School of Public Health.
Sten H. Vermund, MD, PhD. Dean and Anna M.R. Lauder Professor of Public Health, Yale School of Public Health; Professor of Pediatrics, Yale School of Medicine.

Introduction

The urgent need to stop the spread of COVID-19 is among the most important health policy challenges of our lifetimes. Millions of lives are at stake globally, and the economic security of tens of millions of Americans is threatened.

In this white paper, we discuss the potential effectiveness of the universal adoption of homemade cloth facemasks in mitigating this public health crisis; we find that this policy could have very large benefits, but that it should be coupled with policies that protect and increase the availability of medical masks for frontline healthcare workers.

We estimate that the benefits of *each additional cloth mask* worn by the public are conservatively in the $3,000-$6,000 range due to their impact in slowing the spread of the virus. The benefits of each medical mask for healthcare personnel may be hundreds of times larger, and there is an ethical imperative to safeguard frontline healthcare workers. We must both encourage universal mask adoption *and* deal with the urgent policy priority that front-line healthcare workers face shortages of personal protective equipment, such as N95 respirators and surgical masks.

Current medical advice from the CDC, the US Surgeon General's Office, and WHO discourages mask-wearing by the general public. This is due primarily to the shortage of protective equipment for healthcare workers as well as the limited evidence that non-

medical masks protect the wearer from infection.[1] Thus, masks are currently only recommended for healthcare workers, and in some circumstances, for symptomatic individuals while receiving care.

However, there is broad agreement about two crucial points:

- People infected with the SARS-COV-2 virus can have minimal symptoms or can be completely asymptomatic.[2] Thus, seemingly healthy people, including young people, are spreading the virus by transmitting it to others.
- Masks, including cloth masks and surgical masks, have measurable efficacy at preventing infected people from transmitting viruses to others.[3]

These facts suggest that it is not sufficient only for people with symptoms to wear masks. Adoption of masks by everyone – including those with no symptoms – could slow the spread of the virus.[4] Additionally, masks may have some value in protecting susceptible individuals, although of course they are not a substitute for other

---

[1] For example, Dr. Jerome Adams, the Surgeon General, tweeted, "They are NOT effective in preventing general public from catching #Coronavirus, but if healthcare providers can't get them to care for sick patients, it puts them and our communities at risk!" (https://twitter.com/surgeon_general/status/1233725785283932160) . The Surgeon General confirmed in an interview on April 1 that the Surgeon General's office has asked the CDC to reevaluate this advice.

[2] Japanese National Institute of Infectious Diseases. Field Briefing: Diamond Princess COVID-19 Cases, 20 Feb Update. https://www.niid.go.jp/niid/en/2019-ncov-e/9417-covid-dp-fe-02.html (Accessed on March 01, 2020).

[3] See, for example:

Davies, A., Thompson, K.A., Giri, K., Kafatos, G., Walker, J. and Bennett, A., 2013. Testing the efficacy of homemade masks: would they protect in an influenza pandemic? *Disaster medicine and public health preparedness*, *7*(4), pp.413-418.

Ferguson, N.M., Laydon, D., Nedjati-Gilani, G., Imai, N., Ainslie, K., Baguelin, M., Bhatia, S., Boonyasiri, A., Cucunubá, Z., Cuomo-Dannenburg, G. and Dighe, A., 2020. Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand. *Imperial College, London. DOI: https://doi. org/10.25561/77482*.

Jefferson, T., Foxlee, R., Del Mar, C., Dooley, L., Ferroni, E., Hewak, B., Prabhala, A., Nair, S. and Rivetti, A., 2008. Physical interventions to interrupt or reduce the spread of respiratory viruses: systematic review. *Bmj*, 336(7635), pp.77-80.

Rengasamy, S., Eimer, B. and Shaffer, R.E., 2010. Simple respiratory protection—evaluation of the filtration performance of cloth masks and common fabric materials against 20–1000 nm size particles. *Annals of occupational hygiene*, *54*(7), pp.789-798.

van der Sande, M., Teunis, P. and Sabel, R., 2008. Professional and home-made face masks reduce exposure to respiratory infections among the general population. *PLoS One*, *3*(7).

[4] Obviously, individuals with symptoms should quarantine entirely. Further, while we are not aware of studies that demonstrate that a sick person can become sicker due to mask-wearing, there is a plausible mechanism by which that could occur. This suggests that mask-wearing should be limited to circumstances in which the mask-wearer could otherwise contaminate others.

precautions.[5] While physical distancing measures (often called "social distancing") are of paramount importance in preventing the spread of the virus, they cannot be fully enforced. People interact at close quarters when they perform essential activities such as buying food or seeking healthcare, and cashiers or delivery workers may interact with hundreds of people a day. Preventing the transmission of the virus from asymptomatic individuals in such cases is likely the principal benefit of broader mask adoption. For example, in settings in which a worker interacts with the public, both the worker and the public are safer if the other party is wearing a mask.

An important concern is the hoarding of medical masks before there is adequate supply for front-line medical workers. Non-medical alternatives should therefore be considered. For example, there is scientific evidence that homemade cloth masks can prevent viral transmission.[6] Encouraging *production* of cloth masks may help counteract and discourage medical mask hoarding; this can include homemade production and perhaps industrial production, but only to the extent that supply chains do not interfere with those for critically important medical masks. People equipped with cloth masks may feel more comfortable donating existing respirators and surgical masks to medical personnel and first responders. Thus, encouraging the production of cloth masks, including homemade masks, could help protect healthcare workers. Due to the serious concern that any mask recommendation will lead the public to demand more surgical and N95 respirators, any recommendation for broader mask use should be coupled with policies designed to improve their availability to healthcare workers, including subsidies, invoking the Defense Production Act (DPA), and mandating that orders of medical masks from healthcare workers must be given absolute priority.

The Economic Value of Masks

To compute the value of masks, we need to know by how much masks impede the transmission of the SARS-COV-2 virus and the value of reductions in transmission. To analyze the impact of masks on viral transmission, we consider the relationship between norms of mask-use and viral spread at the country level.

Figure 1 shows confirmed positive tests for COVID-19 in all countries with at least 5 million people for which at least 8 days of data are available after the first day with 100 reported cases (select countries are labeled).[7] Time 0 is the first day with 100 cases, and

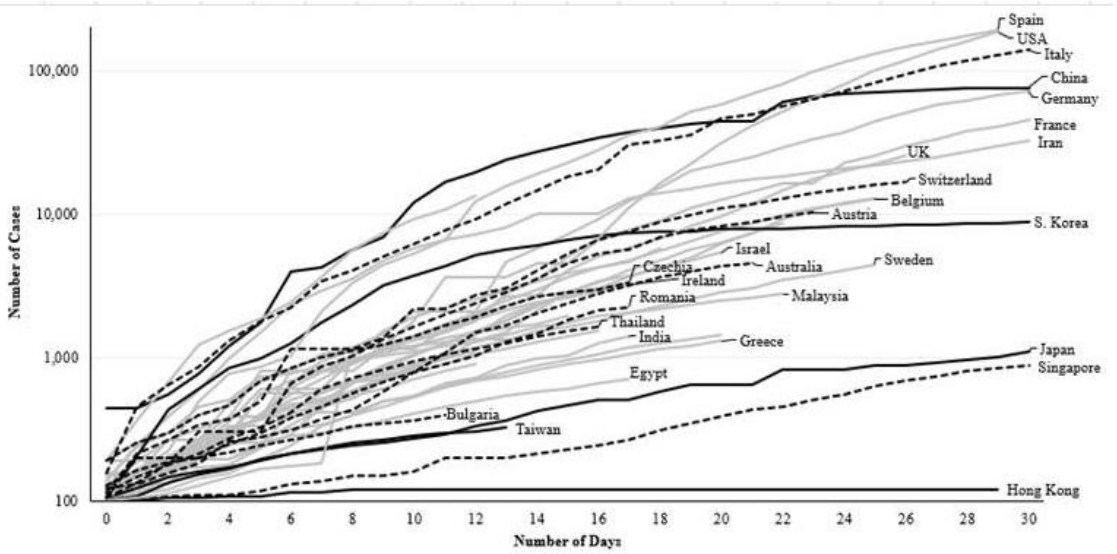
[5] While existing RCTs fail to find a reduction in risk for mask-wearers outside of high-risk settings, these studies (even collectively) are not powered to detect large effects, and they do not address at all the critical question of whether masks prevent transmission of the virus from infected individuals (Cowling et. al. 2009, MacIntyre and Chunghtai 2015).

[6] See van der Sande et. al. 2008, Rengasamy et. al. 2010, Davies et. al. 2013.

[7] The data used in Figure 1 are taken from the COVID-19-Israel Data Respository, https://github.com/COVID-19-Israel/Covid-19-data (Accessed on April 1st, 2020). Jason Abaluck undertook the regression analysis and we are grateful for the research assistance of Emily Crawford.

the figure shows the progress of the epidemic thereafter. Countries with pre-existing norms that all sick people wear masks are shown with a solid black line, countries which do not, but later required masks for infected individuals or the whole population are shown with a dotted line, and countries with no mask norm and no official recommendation as of March 29, 2020 are shown in grey.

Figure 1: Confirmed Positive Tests Since 100 Cases



The pattern in the figure is quite stark: countries with pre-existing norms that sick people should wear masks – including South Korea, Japan, Hong Kong and Taiwan – have been among the most effective at containing the spread of the epidemic. The average daily growth rate of confirmed positives is 18% in countries with no pre-existing mask norms and 10% in countries with such norms.[8]

This evidence is far from definitive: norms do not perfectly predict actual mask availability and use, these countries may have instituted other policies which contained the spread of the epidemic (such as widespread testing in South Korea), and infection rates are imperfectly measured and may appear higher in countries with more testing among other factors.

[8] The "dotted-line" countries which imposed stronger requirements on mask use typically did not do so until the epidemic was well-developed, so we would not expect to see an effect in the graph.

Table 1

	Cases (Positive Tests)			Deaths		
	(1)	(2)	(3)	(1)	(2)	(3)
Impact of Mask Norms	-0.081***	-0.076**	-0.101***	-0.105***	-0.107***	-0.103***
	(0.025)	(0.030)	(0.030)	(0.020)	(0.024)	(0.024)
Number of Countries	42	42	42	24	24	24
Baseline Policy Controls	No	Yes	No	No	Yes	No
Average Policy over 8 Days	No	No	Yes	No	No	Yes
Growth Rate w/o Mask Norms	0.180	0.180	0.180	0.214	0.214	0.214

Notes:

*p<0.1; **p<0.05; ***p<0.01. Regressions with "case" as the outcome include all 42 countries with a population of at least 5 million and at least 8 days since 100 cumulative cases. Regressions with "Deaths" as the outcome include all 24 countries with a population of at least 5 million and at least 8 days since 10 cumulative deaths. Baseline policy controls indicate policy when the trigger event was reached (100 cases or 10 deaths, respectively). Average policy controls are the average of the policy indicator over the 8 days following the trigger event, including the day it was reached. Growth rate without mask norms indicates the average growth rate of the outcome variable in countries without mask norms.

To aid in interpreting the graph, we conduct several additional analyses, shown in Table 1. When we control for the timing of school closings, workplace closings, the cancellation of public events and the closing of public transport, we find that the estimated effect of masks is unchanged or grows slightly larger.[9] Deaths from COVID-19 may be better measured than cases. If we repeat the analysis above using deaths as the outcome variable, we find that the growth rate of deaths is 21% in countries with no mask norms and 11% in countries with such norms. Even with the small number of observations, the impact of masks in all reported analyses is statistically significant at the 5% level, and usually at the 1% level.

There are many factors that cannot be controlled for in an ecological study of this type.[10] One should note that this is a country-level model and we recommend caution in generalizing these results to settings such as hospitals where, especially when masks are scarce, directed use of masks may be desirable compared with universal use. These

[9] These policy variables come from the Oxford COVID-19 Government Response Tracker, https://www.bsg.ox.ac.uk/research/research-projects/oxford-covid-19-government-response-tracker (Accessed on March 30th, 2020). Specifications with "Baseline Policy Controls" control for policies in place at time 0 (100 cases or 10 deaths). Specifications with "Average Policy over 8 Days" controls control for the average value of the policy variables over the first 8 days after time 0.

[10] For example, in addition to norms of mask wearing, handshakes are rare in Japan which may slow the spread of the virus.

results are far from the final word, but they do complement the epidemiological studies of masks cited above. While our analysis principally concerns the impact of norms that *sick* people wear masks, it has direct implications for universal mask adoption. If the causal interpretation of the above results is correct, the impact of mask norms (which increase the likelihood of mask wearing relative to no norm countries) should understate the impact of universal mask adoption for both visibly sick and healthy individuals (who are potentially asymptomatically infected).

Our economic analysis suggests that that even if masks are far less effective than the evidence above suggests, the potential benefits are substantial. If masks reduce the transmission rate of the virus by only 10%, epidemiological models suggest that hundreds of thousands of deaths could be prevented globally,[11] creating trillions of dollars in economic value. According to one commonly used epidemiological model, a 10% reduction in transmission probabilities would generate $3,000-6,000 in value per capita from reduced mortality risk in the US alone.[12] This estimate is conservative with respect to the benefits, as it does not include the economic benefits from a quicker resumption of normal activity. And our estimates above suggest that the effect of masks could be 5-6 times as large. Of course, all such estimates are only as reliable as the underlying epidemiological models. But even if these models overstated risk by a factor of *ten*, the benefits of cloth masks, would *conservatively* be $300 per person.

In a report whose coauthors include former FDA Commission Scott Gottlieb, former FDA Commissioner and former administrator for the Centers for Medicare and Medicaid Services Mark McClellan, former FDA Chief of Staff Lauren Silvis, and Johns Hopkins Center for Health Security Faculty Caitlin Rivers and Crystal Watson, the authors argue that the eventual transition from the current extreme social distancing should involve universal wearing of cloth masks. Dr. Gottlieb argues in a recent interview, "if you mandated that the entire population had to wear a mask when they went out, all those asymptomatic carriers that are now transmitting it through respiratory droplets… it would be much harder for them to transmit it."[13]

Note that all of our arguments for the value of masks for the average person are magnified many times when we consider the current value of medical masks such as

---

[11] Ferguson et. al. suggest that a 10% reduction in viral transmission probabilities (and thus R would reduce by about 10% total deaths from COVID-19 through October).

[12] Greenstone and Nigam (2020) estimate that the total mortality risk from the virus is $60,000 per capita. From Ferguson et. al., a 10% reduction in transmission probability would lead to 10% lower mortality risk, giving $6,000 per capita. With social distancing measures in place, the reduction in mortality risk would be $3,000 per capita.

[13] See Gottlieb, Scott, et. al. (2019) for the report. The interview can be found at Moreno, E., "Former FDA Commissioner Mulls Mask Requirements for Some Age Groups in Public", *The Hill*, March 18, 2020.

N95 respirators for healthcare workers.[14] First, healthcare workers are especially exposed to the virus if they lack protection: they cannot socially distance from their patients, they interact with a large number of patients, and those patients are especially likely to be exposed. Second, if infected, healthcare workers without adequate protection are especially likely to expose others for similar reasons. Third, the people healthcare workers interact with are especially likely to have pre-existing medical conditions and thus high mortality rates from the virus. Fourth, there is substantial evidence that N95 respirators and surgical masks protect healthy individuals, and that N95 respirators are most effective since medical procedures can lead to the aerosolization of droplets which makes medical masks essential.[15] Fifth, as discussed previously, medical masks are extremely effective at preventing infected healthcare workers from transmitting the virus. Sixth, keeping healthcare workers healthy during a pandemic is especially critical to prevent healthcare facilities from being overwhelmed, increasing mortality.[16] Multiplying these factors together, the social value of each N95 mask for a healthcare worker could easily be more than a million dollars per mask.[17] This calculation illustrates the tremendous value of subsidizing the production of medical masks. This calculation, clearly, is in addition to the overwhelming moral imperative to protect healthcare workers during this crisis.

Homemade Masks as an Antidote to Hoarding

Our read of the disparity between the scientific evidence for masks and the public discourse on masks is that policymakers are rightly concerned that an emphasis on the *private* benefits of wearing masks will lead to hoarding of commercially-produced masks reducing availability in the healthcare system. However, we believe that an emphasis on the *social* benefits of mask-wearing and an emphasis on the wearing of homemade masks by the public could lead to a substantial fraction of the health benefits without the negative impacts of mask hoarding.

---

[14] Yan, J., Guha, S., Hariharan, P. and Myers, M., 2019. Modeling the Effectiveness of Respiratory Protective Devices in Reducing Influenza Outbreak. *Risk Analysis*, *39*(3), pp.647-661.

[15] Long, Y., Hu, T., Liu, L., Chen, R., Guo, Q., Yang, L., Cheng, Y., Huang, J. and Du, L., 2020. Effectiveness of N95 respirators versus surgical masks against influenza: A systematic review and meta-analysis. *Journal of Evidence-Based Medicine*.

[16] Fong, M.W., Gao, H., Wong, J.Y., Xiao, J., Shiu, E.Y., Ryu, S. and Cowling, B.J., 2020. Nonpharmaceutical Measures for Pandemic Influenza in Nonhealthcare Settings-Social Distancing Measures. *Emerging infectious diseases*, *26*(5).

[17] The value of the above parameters is difficult to know, as in normal times, healthcare workers would not operate without protective equipment. To take one back of the envelope calculation, if healthcare workers are 10 times as likely to become infected without adequate protection, three times as likely to infect others, encounter patients with a 6x higher mortality rate than the average person, our $6,000 value above would translate to more than $1 million per mask.

An example of a socially influenced mask movement is the Czech Republic. In the Czech Republic, homemade mask-making was led by celebrity influencers, and the country went from masks being unusual to being nearly universal in 10 days.[18]

We are also concerned that recent media and other reports have emphasized the private benefits of mask-wearing (that is, infection protection to the wearer) without discussing the efficacy of non-medical fabric face masks in lowering transmission.[19] This could exacerbate existing supply shortages for hospital-quality masks. Healthcare leaders can responsibly respond to this information by emphasizing the relative efficacy of cloth masks in preventing transmission and the need to increase home production.

[18] See https://www.youtube.com/watch?v=HhNo_IOPOtU&feature=youtu.be.

[19] See, for example, the recent New York Times Op Eds, Tupekci,, Zeynep, "Why Telling People they don't need masks Backfired", New York Times, March 17, 2020 or Sheikh, Knvul, "More Americans Should Probably Wear Masks for Protection", March 27, 2020.

Policy Recommendations

Given the evidence of the benefits of universal mask-wearing and the urgent need for medical masks for health workers, we have two principal recommendations. Political officials should:

1) Promote every market and policy lever to increase the production of medical grade masks and guarantee adequate supply for healthcare workers.
    - Suppliers who produce and sell medical masks should be heavily rewarded. State and federal governments should authorize large subsidies for medical masks. This will expand manufacturing capacity while increasing the affordability of medical masks for healthcare providers. Subsidies many times greater than the usual price of masks are called for to properly incentivize production.
    - Priority for all mask orders should be given to medical personnel, using fines or other penalties for manufacturers who fail to prioritize such orders.
    - The Defense Production Act should be invoked to increase production of medical grade masks. However, care must be taken to heavily reward private firms who efficiently produce medical masks or the concurrent supply from the private market will be undermined.
    - Technologies and strategies for mask sterilization or reprocessing should be developed and deployed as a stopgap until sufficient N95 masks are available for all health workers.
2) Emphasize that <u>everyone</u> should make and wear cloth masks in public at all times, not just those with symptoms. Once surgical masks are no longer in short supply, encourage the universal adoption of these higher-quality protective devices.

Additionally, political officials can and should lead by:

- Themselves wearing cloth masks in public at all times. If these masks are obviously homemade, this will emphasize the pro-social benefits of protecting both healthcare workers (who need commercial masks) and the public at large.
- Emphasizing that mask wearing is a complement to other social distancing measures, not a substitute. [20] Mask wearers who violate social distancing recommendations continue to place themselves and others at high risk.

[20] See, Pourbohloul, B., et.al. 2005 for a discussion of the relative efficacy of various control strategies.

- Supporting or requiring mask-wearing in essential services such as grocery stores where employees have many contacts in a day.
- Emphasizing that one of the main goals of mask wearing is to protect others (As we have seen from the recent spate of COVID-19 cases among public officials, it is reasonable for asymptomatic public officials to behave as if they are at constant risk of infecting the public and to take precautions in their interactions with others).
- Reaching out to visible persons such as media members and strongly encouraging them to do the same.
- Encouraging and demonstrating the correct production and use of homemade masks.
- Providing public health messages with mask-making instructions and instructions on fit. For example, one of the limitations of homemade masks identified by Davies et. al. (2013) is the poor fit achieved by amateur mask-makers. For example, public health instructions would inform individuals with beards to trim the beard to achieve the best fit. Mask users should also be instructed to wash hands after removing masks and wash or dispose of masks after repeated use.
- Partnering with non-medical mask industry to provide free or reduced-price cloth masks to everyone.

Conclusion

The economic case for universal mask wearing is convincing and urgent, but the moral need to provide adequate equipment to frontline healthcare workers is an even higher imperative. Enacting policies to increase medical mask production, and concurrently encouraging the widespread production and use of cloth masks can achieve both objectives. Public officials should encourage and support universal cloth mask adoption immediately. These masks should be dust-prevention quality (as sold in hardware stores) or home-made fabric masks that are worn snugly) until which time as surgical or N95 masks are no longer in short supply.

Outside of crises, policies do not exist where a few dollars of expenditure per person can produce thousands of dollars in benefit. We are in a rare moment when such benefits are achievable--this is an urgent crisis and action is necessary.

References to Academic Articles:

Cowling, B.J., Chan, K.H., Fang, V.J., Cheng, C.K., Fung, R.O., Wai, W., Sin, J., Seto, W.H., Yung, R., Chu, D.W. and Chiu, B.C., 2009. Facemasks and hand hygiene to prevent influenza transmission in households: a cluster randomized trial. *Annals of internal medicine*, 151(7), pp.437-446.

Davies, A., Thompson, K.A., Giri, K., Kafatos, G., Walker, J. and Bennett, A., 2013. Testing the efficacy of homemade masks: would they protect in an influenza pandemic? *Disaster medicine and public health preparedness*, *7*(4), pp.413-418.

Ferguson, N.M., Laydon, D., Nedjati-Gilani, G., Imai, N., Ainslie, K., Baguelin, M., Bhatia, S., Boonyasiri, A., Cucunubá, Z., Cuomo-Dannenburg, G. and Dighe, A., 2020. Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand. *Imperial College, London. DOI: https://doi. org/10.25561/77482*.

Fong, M.W., Gao, H., Wong, J.Y., Xiao, J., Shiu, E.Y., Ryu, S. and Cowling, B.J., 2020. Nonpharmaceutical Measures for Pandemic Influenza in Nonhealthcare Settings-Social Distancing Measures. *Emerging infectious diseases*, 26(5).

Gottlieb, S., Rivers, C., McClellan, M.B., Silvis, L., and Watson, C., "National Coronavirus Response: A Road Map to Reopening," American Enterprise Institute, March 28, 2020.
Greenstone, M. and Nigam, V. 2020. Does Social Distancing Matter? *BFI Working Paper, No 2020-26.*

Jefferson, T., Foxlee, R., Del Mar, C., Dooley, L., Ferroni, E., Hewak, B., Prabhala, A., Nair, S. and Rivetti, A., 2008. Physical interventions to interrupt or reduce the spread of respiratory viruses: systematic review. *Bmj*, 336(7635), pp.77-80.

Long, Y., Hu, T., Liu, L., Chen, R., Guo, Q., Yang, L., Cheng, Y., Huang, J. and Du, L., 2020. Effectiveness of N95 respirators versus surgical masks against influenza: A systematic review and meta-analysis. *Journal of Evidence-Based Medicine*.

MacIntyre, C.R. and Chughtai, A.A., 2015. Facemasks for the prevention of infection in healthcare and community settings. *BMJ*, 350, p.h694.

Pourbohloul, B., Meyers, L. A., Skowronski, D. M., Krajden, M., Patrick, D. M., & Brunham, R. C. (2005). Modeling control strategies of respiratory pathogens. *Emerging infectious diseases*, *11*(8), 1249.

Rengasamy, S., Eimer, B. and Shaffer, R.E., 2010. Simple respiratory protection—evaluation of the filtration performance of cloth masks and common fabric materials against 20–1000 nm size particles. *Annals of occupational hygiene*, *54*(7), pp.789-798.

van der Sande, M., Teunis, P. and Sabel, R., 2008. Professional and home-made face masks reduce exposure to respiratory infections among the general population. PLoS One, 3(7).

Yan, J., Guha, S., Hariharan, P. and Myers, M., 2019. Modeling the Effectiveness of Respiratory Protective Devices in Reducing Influenza Outbreak. *Risk Analysis*, 39(3), pp.647-661.