Received: 8 September 2020 | Accepted: 8 September 2020

DOI: 10.1002/mds3.10120

RESEARCH ARTICLE

MEDICAL DEVICES & SENSORS WILEY

COVID-19: Facemasks, healthcare policies and risk factors in the crucial initial months of a global pandemic

Jubair Ahmed[1] | **Anthony Harker**[2] | **Mohan Edirisinghe**[1]

[1]Department of Mechanical Engineering, University College London, London, UK

[2]Department of Physics and Astronomy, University College London, London, UK

Correspondence
Mohan Edirisinghe, Department of Mechanical Engineering, University College London, London WC1E 7JE, UK.
Email: m.edirisinghe@ucl.ac.uk

Abstract

Previous pandemics have shown that facemask use becomes highly popular in public settings due to fear of the disease spreading. There is, however, a lack of strong scientific evidence that facemasks can significantly reduce the spread of respiratory diseases and as such, most governing policies do not mandate these coverings. There is a stark contrast between the policies and acceptance of facemasks across different geographies. In this work, several data sources have been thoroughly analysed to elucidate how viral diseases are transmitted and spread with particular emphasis on the novel SARS-CoV-2 virus which is causing an outbreak of COVID-19. The different types of facemasks and respirators are also explained, the nature of their design and their efficacy is also examined. Several key factors which have been hypothesised to contribute to the spread of viral infections are elaborated in detail including the effect of temperature and humidity, public transportation systems, population density, socio-economics and sociology. In this work, data are analysed to explain how the disease is spread, how facemasks function and the differences in the number of initial cases based on several contributing factors to the spread of disease. There are also some dangers in automatically recommending community facemask wearing, such as a reduction in the immune system functionality from the reduced exposure to microbes and the disposal issues which result from the large-scale use of such materials. The questions of whether facemasks are useful in a community setting or if they divert valuable material away from critical healthcare providers are discussed.

KEYWORDS
COVID-19, facemask, healthcare policy, public health, respiratory disease

1 | INTRODUCTION

The severe acute respiratory syndrome (SARS) outbreak of 2003 took a huge toll on lives and the economy and highlighted the importance of personal protective equipment (PPE) and face masks for front-line staff. 17 years later, the outbreak of SARS coronavirus 2 (SARS-CoV-2) is significantly more widespread to nations all over the world. There is a consistent recommendation of the use of facemasks for individuals that show symptoms and for those in healthcare environments; however, there is a discrepancy observed when it comes to the general public and in communities (MOH, 2020; WHO, 2020). There is a stark contrast in the behaviour and requirement for face

masks between the Western countries such as the United Kingdom and the United States of America, compared to eastern countries such as China and the Philippines. This article will review the protective capacity of facemasks whilst comparing and contrasting the use of facemasks with infection rates and the spread of the disease.

1.1 | How is the disease spread?

SARS has been shown to spread most commonly through direct contact to the mucous membrane with infectious respiratory droplets or through contact of contaminated surfaces which leads to indirect exposure to the mucous membranes of the eyes, nose or mouth (Peiris et al., 2003). It is thought that an infected human host can generate particles as small as 100 nm (Roy & Milton, 2004). If the outer surface of the protective equipment is not adequately water repellent, contaminated droplets can stick to the material and then be absorbed into it, if it is also water absorbent (Li et al., 2006). It has further been established that SARS-CoV-2 can be shed through the oral–faecal route, although modern worldwide sanitary precautions significantly reduce that concern (Zhang et al., 2020).

SARS coronaviruses have a size distribution between 60-200 nm and are not regularly shaped, in contrast to the influenza virus which has a size distribution of 80-1200 nm and has a distinct globular shape (Goldsmith et al., 2004; Stanley, 1944). There is a concern that viruses can thus have the ability to penetrate through the mask and spread via liquid diffusion by a capillary effect as the expelled air will moisten the mask (Li et al., 2006). Condensation can occur in the masks due to the higher temperature and humidity of expired air; these droplets are then expelled during speech and can accelerate the wetting of the material. The mechanical act of respiration can thus lead to penetration of these droplets, and the mask becomes a collector of viruses. These processes are typical physical processes of coupled heat transfer and mass transfer in porous materials such as can be seen with the common non-woven textiles used as filters (Yi et al., 2005). Microbes such as bacteria and viruses can reside on surfaces and in masks for a significant period.

Due to the rarity of long-range infections, the current view is that the viability of viruses such as influenza A in aerosol form is highly limited and therefore less of a concern than large expelled droplets and coming into direct contact (Gawn et al., 2008). Aerosols can be defined as solid or liquid suspensions in the air that are small enough to remain airborne for prolonged periods due to their low settling velocity (Fernstrom & Goldblatt, 2013). The settling time for particles of about 5 μm can be over an hour and particles of <3 μm can remain airborne indefinitely due to their low mass (Knight, 1980). The act of coughing or sneezing can generate a substantial number of particles which mostly fall within the <5-10 μm range (Nicas et al., 2005). These particles then rapidly shrink in size as they traverse the air via evaporation and thus behave as aerosols (Lemieux et al., 2007). As aerosols remain airborne, they can travel over large distances and have the potential to cause long-range infection (Cummins et al., 2020; Tellier, 2006).

The surface stability and aerosol stability of SARS-CoV-2 was experimentally evaluated and compared to the SARS-CoV-1 virus (van Doremalen et al., 2020). The viability of the viruses was tested in five different environmental conditions; on stainless steel, copper, plastic, cardboard and as aerosols. SARS-CoV-2 remained viable for at least 3 h in aerosol form (<5 μm) and was comparable to the results of SARS-CoV-1. The SARS-CoV-2 virus was more stable on stainless steel and plastic than on cardboard and copper as the virus could be detected 72 h following application onto these surfaces. Another study which looked into the coronavirus survival on various surfaces used transmissible gastroenteritis virus and mouse hepatitis virus as models for the SARS-CoV coronavirus and found that on stainless steel, the virus could persist as long as 28 days at a temperature of 4°C (Casanova et al., 2010).

The isolation rooms of 13 individuals that tested positive with COVID-19 were investigated for the transition potential of SARS-CoV-2 on common personal items such as mobile phones, television remotes and exercise equipment (Santarpia et al., 2020). It was found that both the symptoms and viral shedding from the individuals considerably varied. Three types of samples were taken: surface, high volume air and low volume personal air samples. Overall, 76.5% of all personal items tested positive for SARS-CoV-2 under polymerase chain reaction sampling. Of the personal items, 81.3% of miscellaneous personal items such as tablet computers and reading glasses showed signs of viral DNA. 83.3% of mobile phones and 64.7% of television remotes tested positive for the virus. Of the total room surfaces samples, 80.4% tested positive for SARS-CoV-2. Air samples from the rooms were found to be 63.2% positive whilst samples taken in the hallways outside the rooms were 66.7% positive. The study suggested the viruses expelled from infected individuals may be transported by aerosol processes, even in the absence of a cough and also shows the highly transmittable nature of this virus.

The potential transmission of SARS-CoV-2 through the opening of the eyes has not yet been well studied. Coronaviruses have been well established to cause ocular infection in various animals such as murines and felines (Seah & Agrawal, 2020). A study in 2004 tested the tears of 36 suspected SARS patients, three were positive for the virus and in one case, RNA was found in stool respiratory swabs and tear samples (Loon et al., 2004). The study suggested that the disease could be spread through ocular tissues and secretions. However, it is unclear how the virus may end up in the tears, with theories pointing towards the conjunctiva being an inoculation site for the virus from infected respiratory tracts (Seah & Agrawal, 2020). Concrete evidence that the virus can cause the disease through the eyes only is missing and it is not widely believed that this is a means for transmission (Chan et al., 2004; Tong & Lai, 2005).

The evidence shown here mostly suggests that the virus is transmitted through aerosolised particles which are thought to be viable on surfaces and perhaps even airborne. However, there is no compelling evidence to correlate the presence of SARS-CoV-2 on surfaces and air to the infectious viability of the virus. What remains evident is that the virus enters the respiratory system through the nose or mouth. Facemasks must therefore act as a physical barrier

and their efficacy should be determined on a product-to-product basis.

1.2 | What kinds of face masks are there?

Face masks can be defined as any material which creates a protective barrier between the environment and the entrance of the respiratory system, namely the nose and the mouth. Face masks are intended to prevent the transmission of infected droplets into the wearer's system and to trap pathogenic microbes that may also enter through ordinary respiration. Facemasks and respirators come in many forms. A respirator can be a full or half-face mask that is designed to protect against very hazardous environments commonly pertaining to protection against fumes, gases, vapour and harmful particulate. In the interest of simplicity, we are including respirators in the same category as 'face masks' as they cover the mouth and nose of the wearer and can protect against microbes. We can broadly define three categories of facemasks with increasing level of anticipated protection: cloth facemasks (including home-made), surgical masks and respirators. The main categories of facemasks and their attributable properties are illustrated in Figure 1.

A basic personal facemask typically consists of cloth material, either synthetic or natural, which is worn across the mouth and the nose and comes with elastic straps that maintain a fit to the face (Shakya et al., 2017). Nations that commonly see the daily use of facemasks happen to fall mostly Asia with countries including China, Nepal, Bangladesh, India, Sri Lanka and Indonesia. These basic level face protections have no universal standard and offer only a first-level protection against large droplets. These facemasks are also deemed to be disposable and should be replaced at least daily under ideal circumstances as the cloth may harbour microbes that can later cause infection. The use and effectiveness of these masks in community settings is disputed but it is undeniable that even a basic layer of defence would reduce transmission in some measurable way. With the high demand for facemasks in epidemics like COVID-19, facemask materials become scarce and individuals resort to home-made improvised alternatives that aim to cover the face with basic cloth materials such as with scarfs. As there is no set standard for a basic facemask, it is not entirely possible to determine what the microstructure of an ideal protective facemask structure may look like (Rengasamy et al., 2010).

Surgical masks are standard procedure in operating theatres and are designed to prevent the transmission of infection from the surgical site during a procedure (Belkin, 1996). Surgical masks are fluid resistant and will protect the wearer from large droplets, they will however not protect against small airborne particles. They are loose-fitting: they usually include a simple wire strip to be shaped around the nose, but they allow leakage from around the edges. The Food and Drug Administration (FDA) approves the use of surgical masks for operating theatres but their filtration capabilities are not regulated. Facemasks that fall in the category of basic and surgical do not have a mechanism in which they can fully protect the wearer from outside particles and are highly ineffective against respiratory infections in the absence of a proper facial seal (Brown, 2019).

Respirators are distinct from normal face masks because they are designed to protect against certain pre-defined levels of contaminants in the air. N95 filtering respirator facemasks are used to protect the

FIGURE 1 Diagrammatic overview of the major types of masks, indicating anticipated protection and based on design and relative costs

human respiratory system from airborne particles that are associated with known respiratory and cardiovascular diseases (WHO, 1999). The N95 standard of respirator is now most commonly used in industrial and healthcare environments and is considered highly efficient in its filtration capability. It was shown that these masks are over 95% efficient against penetrating particle sizes between 100 to 300 nm, the efficiency against particles over 750 nm increases dramatically to over 99.5% (Qian et al., 1998). These N95 rated facemasks are tight-fitting and permit minimal leakage. N95 designations are given to filter material that can filter at least 95% of the most penetrating particle size, N99 for at least a 99% filtration efficiency and N100 for at least 99.97% efficiency. High-efficiency particulate arrestance (HEPA) filters are comparable to N100 filters (Derrick & Gomersall, 2004).

The filters that are used in all the aforementioned facemasks are fibrous and are generally constructed from non-woven mats of fine fibres. The fibre diameter, porosity (open space between fibre strands) and the filter thickness contribute to the efficiency of the filter in trapping particulates (Lee & Liu, 1982). There are three accepted mechanisms by which fibres can filtrate: inertial impact, interception and diffusion (Ramarao et al., 1994). Inertial impact is the mechanism by which larger particles are collected on the fibres due to their large size, mass and higher inertia; interception applies to larger particles as they pass close to the fibres and become trapped; diffusion is the mechanism of trapping smaller particles which are bombarded by the air stream and come into contact with the fibres. Electrostatically charged non-woven materials can also be used in filtration to improve the particulate trapping efficiency as oppositely charged particles are attracted to the charged fibrous mesh, this method filters particles of all sizes (Wang, 2001). The mechanisms are summarised in (Figure 2).

A classical blue surgical mask was measured to have an average pore size of about 19.3 μm with a filter thickness of about 0.3 mm (Leonas & Jones, 2003). Conversely, N95 masks have a fibrous filtration membrane with an average fibre diameter of about 7.8 μm and with an average membrane thickness of around 1.7 mm (Balazy et al., 2005). N95 masks are made of a thinner non-woven polypropylene fibrous mesh than surgical masks, they have a smaller pore size and thicker membrane size, all contributing to their increased efficiency in filtering small particles, the charge commonly present on N95 mask material can further increase filtration (Rengasamy et al., 2014). Therefore, physical microstructure of the material plays a substantial role in the efficiency of facemasks; however, there must also be a balance in the pressure drop of the material whilst respiring, which could otherwise make breathing difficult (Grinshpun et al., 2009).

2 | EFFECTIVENESS OF FACEMASKS

2.1 | Facemask use in different countries

The use of personal facemasks is thought to provide the wearer with a short-term practical solution against air pollution. It is common in many developing nations, as exposure to particulate matter is associated with respiratory and cardiovascular health deterioration (Davidson et al., 2005). Therefore, less economically developed countries or countries with a high level of air pollution have already been accustomed to the regular wearing of personal face masks.

A study into the use of facemasks in the prevention of respiratory infection found that individuals were more likely to wear facemasks if there was a perceived susceptibility to being exposed to life-threatening diseases (Sim et al., 2014). They also found that perceived barriers preventing the use of facemasks were discomfort but more importantly embarrassment. Therefore, countries such as China who have had outbreaks of viruses in the past decades such as the SARS-CoV-1 and the Middle East respiratory syndrome (MERS) coronaviruses, see their population perceiving a high susceptibility to respiratory diseases. During the peak of the 2003 SARS epidemic in Hong Kong, 76% of the population wore a face mask (Lo et al., 2005). Furthermore, the normality of public facemasks in China has increased social acceptability and therefore there is less embarrassment compared to countries with low susceptibility of such previous diseases, such as with the United States. A study which investigated the SARS-related perceptions in Hong Kong found that over 90% of the respondents believed that using facemasks in public was an efficacious means of preventing a resurgence of SARS after the pandemic was officially deemed over (Lau et al., 2005). The economic impact of China spans across many

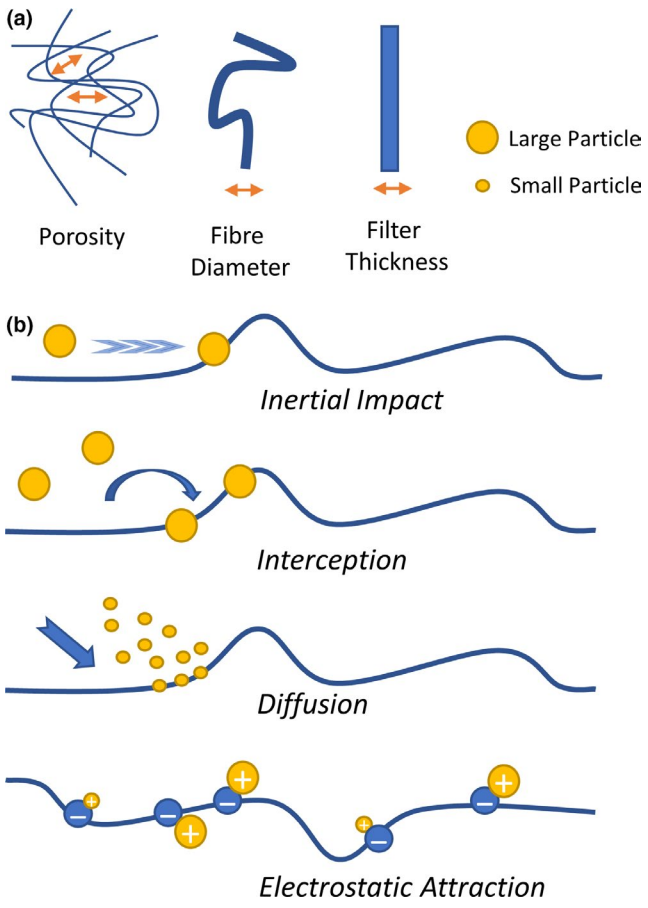

FIGURE 2 Summary of fibrous filtration mechanisms; (a) physical factors affecting filtration and (b) mechanisms of filtration

Asian countries including Korea, Singapore and Malaysia, reducing the social stigma attached to the regular use of facemasks.

The United States Surgeon General has publicly advised against the purchasing of masks for healthy people as it leads to limited supplies for healthcare services (Feng et al., 2020). Furthermore, community facemask use in the United States of America was discouraged in the early stages of the pandemic and was often argued to not offer an effective protection against infection of coronaviruses (Elachola et al., 2020). It comes after the supposed lack of evidence that these face masks can protect against respiratory infections in community settings and has been previously acknowledged in recommendations from influential European countries such as Germany and the UK. In Germany, the initial consensus was that there is not enough evidence to prove that a surgical mask can significantly reduce infections and that by its wearing in public, it can lull the public into a false sense of security (FMH, 2020). In the UK, the government initially said that face masks play a very important role in hospitals but there is little evidence that they can benefit members of the public (NHS, 2020a). Across Europe, it is highly recommended that the public practise proper hand hygiene by washing hands with soap and water for at least 20 seconds: and it was generally believed that this approach is far more effective than the community use of facemasks.

There is significant variation in societal and cultural paradigms for the use of face masks between Asian countries, European and North American countries. In Asia, as mentioned previously, the stigma attached to the community use of facemasks is very little. However, in Europe and North America, there is stigmatisation for healthy people wearing facemasks which can cause racial aggravations, revised public education is therefore required. If we take the 2003 SARS outbreak as an example, the responses between the West and the East were very dissimilar. In the West, media imagery of Asian countries with high infection rates and the majority of the population wearing facemasks sparked a symbolism with the disease, that some have even compared facemasks with SARS to condoms with HIV/AIDS (Syed et al., 2003). This type of connotation can lead to cultural taboos that reduce compliance with the universal wearing of masks.

However, if there were a universal use of facemasks, some of these concerns might be alleviated. The extensive use of facemasks is not without concerns: disposal of masks and improper use can have huge environmental side effects.

2.2 | Effectiveness of facemasks

A study into the effectiveness of five 3 M manufactured face masks against aerosolised *Mycobacterium chelonae abscessus* found that the efficiencies of these masks were all above 97% (Chen et al., 1994). This study tested the following masks: (a) Aseptex sub-micron moulded surgical mask, 1812, (b) 3 M Healthcare Particulate Respirator, 1814, (c) 3 M Dust/Mist Respirator, 8715, (d) 3 M Dust/Welding Fume Respirator, 9920 and (e) 3 M High Efficiency Respirator, 9970 (HEPA). *Mycobacterium abscessus* are gram-positive bacteria which are about 500 nm wide with an average length between 1 and 3 μm. Although this is much larger than the SARS-CoV-2 virus, this model is relevant as it is transmitted via aerosolised droplets (Aitken et al., 2012; Lee et al., 2015). In the order of the listed 3 M-manufactured facemasks, the tested efficiencies were as follows: 97.5 ± 0.47%, 98.6 ± 0.22%, 97.2 ± 1.64%, 99.96 ± 0.02% and over 99.99 ± <0.01% for the most efficient HEPA respirator.

A cluster-randomised trial compared the household use of surgical masks, non-fitted N95 masks and no masks in the prevention of influenza-like illness (ILI) and was conducted in the winter seasons of Australia during 2006 and 2007 (MacIntyre et al., 2009). In this study, 286 adults from 143 households were recruited whom had been exposed to a child with clinical respiratory illness. It was found that the use of face masks significantly reduced the risk of ILI even though <50% of the participants wore masks for most of the time. The study concluded that the household use of facemasks led to low adherence and is likely to be ineffective for controlling seasonal respiratory diseases but in the event of a severe pandemic (such as COVID-19), the role of facemasks can be more impactful in the prevention of disease spreading.

It is not beyond logic to expect that home-made masks offer some sort of respiratory protection to the user and could impede the spread of infectious droplets. Researchers at Cambridge University tested the efficacy of home-made masks in preventing influenza (Davies et al., 2013). The study involved 21 healthy volunteers aged between 20 and 44 who were given facemasks made of improvised household fabrics. Volunteers were left to fit their own facemasks, being more representative of actual scenarios where the fit would differ from person to person. Surgical masks were used as a control in the experiments. They found that home-made masks significantly reduced the number of microorganisms that were expelled; however, surgical masks were 3 times more effective than the improvised masks at blocking transmission. Against the microorganism *B. atrophaeus*, vacuum cleaner bags were found to have a mean filtration efficiency of 94.35%, followed by a tea towel at 83.24%, cotton T-shirt at 69.42%, antimicrobial pillowcase at 65.62%, scarf at 62.30%, linen at 60.00% and silk at 58.00%. The study also concluded that a home-made facemask should only be used as a last resort but that it was better than having no protection at all.

A randomised trial of 446 nurses which aimed to investigate the effectiveness of surgical masks compared to N95 masks found similar instances of confirmed influenza cases within the two groups (Loeb et al., 2009). The data suggest that surgical masks and N95 respirators are similarly effective in reducing the transmission of droplets into the respiratory system: 23.6% of surgical mask-wearers had laboratory-confirmed influenza compared to 22.9% of N95 users. The degree of symptoms in the confirmed cases varied significantly, in-line with normal influenza cases. The evidence gathered here points to external factors in the spread of disease such as adherence to wearing masks, good hand hygiene and efficiency of the individual's immune system.

A recent controlled study in four patients wearing surgical and cotton masks evaluated the effectiveness of cotton and surgical masks in filtering SARS-CoV-2 (Bae et al., 2020). The study used

the influenza virus as a model for SARS-CoV-2 It was found that neither cotton nor surgical masks were effective in filtering the virus during coughs from the infected patients despite previous evidence that they could filter influenza (Johnson et al., 2009). The outer surfaces of the masks were found to be highly contaminated with the virus, offering additional routes of entry into the respiratory system such as during facemask removal or inhalation. The evidence here indicates that comparisons with influenza may not be a perfect model and that these masks are not very effective in preventing SARS-CoV-2. Meta-analysis of over 20 per-reviewed and pre-print studies to assess mask effectiveness at preventing respiratory viral infections in humans has suggested that mask-wearers had up to a one-third reduction in infection from all respiratory viruses compared to the control group (Relative Risk = 0.65 (confidence interval 0.47-0.92); Liang et al., 2020). Recent studies have shown the effectiveness of facemasks and face shields among health workers in highly prevalent infection settings (Bhaskar & Arun, 2020; Wang et al., 2020).

Polymeric nanofibres have been studied in laboratory settings for decades now and have proven to provide superior filtration efficiency compared to micro-sized fibres commonly utilised in most facemasks (Li et al., 2019; Leung & Sun, 2020; Zhang et al., 2019). As viruses are typically within the size range of 20–200 nm, they can freely penetrate classical microfilters: nanofibrous polymeric non-woven materials can filter out more than 99% of such small particles (Zeytuncu et al., 2018). The major obstacle with translating this technology into the manufacturing industry has generally been the slow rate of production, however, recently newer techniques have been developed that allow masses of fibres to be produced in less time (Alenezi et al., 2019; Czigany & Ronkay, 2020; Heseltine et al., 2018; Hong et al., 2019; Molnar & Meszaros, 2020). The use of nanofibrous materials also reduces the thickness of the membrane required for efficient filtration, reducing the polymer trail left by the pandemics.

2.3 | Factors that affect the spread of disease

There are many external factors involved in the spread of disease that are specific to geographical location, governmental policies, traditions and cultures. Geography plays a huge influence in the spread of disease as hard-to-reach areas will naturally see slower spread due to the difficulty in traversing the land. Furthermore, geography dictates the fertility and water availability of land which can sustain higher population densities. Diseases spread faster when people interacting in close proximity is the norm (Tarwater & Martin, 2001).

2.3.1 | Temperature and humidity

Temperature is associated with permitting the fusion of viruses into the cellular membrane of hosts which allows them to enter cells and replicate: viruses at low temperatures don't efficiently fuse and therefore cannot inject their genetic material (Brunner et al., 1991; Yunus et al., 2010). However, low environmental temperatures do not affect the person-to-person transmission rate of diseases. Relative humidity (RH) describes the water vapour holding capacity of air at a given temperature whilst absolute humidity (AH) measures the mass of water in the air. In a study with guinea pigs and the transmission of Influenza A, it was found that increased transmission occurred at low temperatures and low humidity (Lowen et al., 2007). A separate group reanalysed the data and found that there was a very strong correlation between absolute humidity and the data presented (Shaman & Kohn, 2009). Shaman et al. (2010) found that the relationship between AH and virus survival rates mirrored observations in the United States of America, where low AH environments would result in influenza epidemics following a two-week lag phase of general flu infections.

As previously mentioned, a study into the survival of two pathogenic viruses found that the viruses could be viable on stainless steel for up to 28 days at an air temperature of 4°C (Casanova et al., 2010). They found that at an RH of 20%, the lowest level of inactivation occurred. The relationship between RH and inactivation was not monotonic, at a low RH of 20% and a high RH of 80%, the virus seems to be the most resilient. At an air temperature of 20°C, inactivation of the viruses was higher, which indicates that the virus is less resistant to higher temperatures. In a further six studies into the effect of humidity and temperature on the survival of the influenza virus, four studies found that survival increased monotonically with low RH (Harper, 1961; Hemmes et al., 1960; Hood, 1963; Loosli et al., 1943). The two other studies observed a bimodal relationship with survival being highest at low RH, minimal at a medium RH and moderate at a high RH (Schaffer et al., 1976; Shechmeister, 1950). In examining the effect of RH and temperature on the aerosol transmission viability, a study showed that transmission decreases as temperature increases from 5 to 20°C and is shown to have halted completely at 30°C (Lowen et al., 2008).

In analysing seasonal patterns of Influenza in varying temperate and tropical regions, a study found that epidemics predominately occur during the winter months when it is cool and dry and solar radiation is low, this trend is also observed in countries across several latitudes worldwide (Tamerius et al., 2011). It was also observed that the seasonal activity of influenza in the tropics appeared to be greater during the rainy seasons.

There is some evidence that humidity affects the immune function of humans, it is thought that the inhalation of dry air inhibits the mucociliary clearance which is normally the self-clearing protective mechanism of the respiratory tract, dried out membranes are more prone to viral infection as this protective layer dries out (Antunes & Cohen, 2007; Salah et al., 1988). Furthermore, the inhibition of this mucociliary clearance in cold climates due to the inhalation of cold air is thought to have a negative outcome on the immune function too (Baetjer, 1967).

Countries with warmer climates such as in Asia often have ubiquitous air conditioning setups which are standard in most retail and hospitality environments. The use of air conditioning can often be a substitute for poor ventilation such as in crowded or highly polluted cities where many rooms are built without window facilities. A case study into the spread of COVID-19 associated with air conditioning in China found evidence that infectious droplet transmission was prompted by the ventilation of air conditioning units in a restaurant (Jianyun et al., 2020). The study also found that the direction of airflow was a key factor for infection where recirculated air could have the potential to infect.

The effect of temperature on the frequency of social gatherings must also be taken into consideration: in temperate climates such as in the United Kingdom, the warmer weather attracts masses of people to communal parks, restaurants and pubs which significantly increase the rate of infection for respiratory diseases (Willem et al., 2012). These events make it difficult to discern the difference between the effects of higher temperatures on the spread of viruses as opposed to lower temperatures, when people are more likely to stay indoors. In high humidity scenarios, breathing can become increasingly difficult, as respiratory diseases such as SARS and COVID-19 further affect breathing, this weather pattern can exacerbate symptoms and lead to a higher toll on the healthcare system (Wanka et al., 2014). Conversely, at very low humidity, the respiratory tract can become irritated, this results in seasonal coughs which can cause virus particles to be more frequently and vigorously expelled from individuals, contributing to the increased spread of disease (Mäkinen et al., 2009).

As the survival of viruses depends on their ability to replicate, and their dependency on a living host, viruses have a limited lifespan away from the body (Pirtle & Beran, 1991). In particular, the SARS-CoV-2 virus requires mammalian hosts as they have a complex respiratory system which is needed for the virus's survival (Lai et al., 2020). The virus still retains a limited viability on surfaces and in aerosol form, where it 'waits' in the hope of being passed onto another host. Viruses released from an infected host are encapsulated and protected within cough droplets. High temperature and low humidity increase the rate of evaporation, it can be theorised that the virus will not survive if these droplets dry out (Linacre, 1977). Therefore, low humidity and high temperature may contribute to the reduction in viral viability in an environmental capacity by deactivation. Additionally, studies have shown that ultraviolet B radiation increases the inactivation rates of viruses (Welliver, 2009).

2.3.2 | Public transportation systems

Human travel undoubtedly plays a key role in the spread of infection. COVID-19 had its epicentre of infection in Wuhan, China and in a matter of months, spread across nearly all the countries in the world. California, a highly populous American state, sees frequent annual epidemics of respiratory diseases which is likely due to its large population and high volume of air traffic (Balcan et al., 2009; Viboud et al., 2006). Air travel is thus a major contributor for spread, but as the majority of flights were grounded in response to the epidemic, the focus shifted to ground transportation systems as a means of viral transmission. Transportation hubs can serve as epidemic centres and countries with extensive transportation networks such as in the United States and Asia can be expected to have a wider initial spread of the virus. The idea that public transport systems pose a higher risk of viral transmission comes from the fact that one encounters a higher occupant density, high likelihood of overcrowding in an enclosed place, poor ventilation which may also recirculate contaminated air and there is a significant duration of exposure to potentially infected individuals (Nasir et al., 2016; Tatem et al., 2006).

In judging the public transport systems around the world, there are a few cities which are renowned for their sheer carrying capacity and interconnectivity. Hong Kong, Tokyo, Singapore, New York, Seoul, Paris, Madrid, Shanghai, Berlin and London are among the top. These cities are spread across three continents, North America, Europe and Asia and are situated in eight countries; China, Japan, Singapore, USA, France, Spain, Germany and the UK. These countries contain notable transportation systems that link key areas of important workplaces to commuters over the city and therefore carry masses of people in which the spread of disease can be amplified. In looking at the factors associated with disease spread and public transport, one must investigate post-epidemic public transport conduct such as facemask compliance, closure of lines/services and relative footfall.

2.3.3 | Population density

Population density describes the spread of people within a given area of land. It goes within reason that the increase in population density will contribute to a greater spread of disease if other precautions are not taken. Increased population density puts individuals closer together: with such a highly contagious and infectious disease as COVID-19, this factor can lead to rapid widespread transmission. Studies into the effect of climate factors and population density of viral chickenpox and measles found that population density is a contributing factor to the number of cases seen in countries with a high population density such as India (Lolekha et al., 2001; Singh & Datta, 1997).

Cruise ships show a good example of large population densities which involve many people who are confined to a limited space over a significant period. One particularly notable case was on the Diamond Princess where the density of people was estimated to be four times that of the epicentre region Wuhan, which led to a large proportion getting infected with COVID-19 (Rocklöv et al., 2020). In modelling the daily reproductive number of COVID-19, there is a strong relationship between the contact rate and the population density. This model shows that there is an increased rate of transmission of the disease in large social gatherings such as a 50,000 crowd music/sports event where the density is extremely high (Rocklöv & Sjödin, 2020).

2.3.4 | Socio-economics

There have been some studies on the relationship between socio-economic status and the risk of becoming infected. Many studies conclude that a lower socio-economic status increases the general risk of infection (Brownstein et al., 2007; Sloan et al., 2011). A low socio-economic status itself is not a cause of infection; however, individuals with a lower socio-economic status tend to be associated with higher risk factors such as smoking, poor diet and living in very close proximity to each other (Alraddadi et al., 2016). The difference in lifestyle choices can be attributed to longer working hours in lower-skilled jobs, difficulty in accessing effective healthcare, overcrowded households and barriers in communication (Dunn, 2002; Mashreky et al., 2010; Nicholson, 1996).

A country's distribution in the sectors of its economy can have a marked difference in the potential for a disease to spread. In a country where the majority of its economy falls in the primary sector, there may be fewer transport links and a lesser need for the population to congregate frequently in one common location such as supermarkets and shopping centres. Primary sectors mostly include farming, fishing and mining and usually involve large areas of land with a low density of people; demand for these jobs is lower than other sectors and as such, deep infrastructure to well-connected cities may not be required (Kenessey, 1987). Conversely, in a country where the dominant sector is secondary, there will be an influx of people to large cities and close living proximities, as jobs such as manufacturing and food processing see very high demands. Shenzhen, China, sees such huge demands for work that the population transformed from under 50,000 people in 2010 to over 10 million currently (Lindtner et al., 2015). In the recent COVID-19 epidemic, countries resorted to lockdown measures, however, primary and secondary sectors are essential in sustaining the economy of the country and other countries which rely on exports of its resources. Therefore, primary and secondary sectors cannot completely shut down, leading to high levels of public transportation and person-to-person transmission of viruses. Countries which predominantly have tertiary or services sectors can afford to have a large proportion of employees working remotely, this means that there is less of a toll on the public transportation systems, contributing to some reduction in the transmission of disease.

2.3.5 | Social norms, culture and traditions

Socially accepted behavioural patterns can alter a region's way of life and thus how human interactions contribute to the person-to-person transmission of disease. For example, in countries such as in the Middle East, South America and Asia, it is traditional to have frequent large gatherings in which family and friends will congregate in substantial numbers to share food. These occasions commonly see individuals in very close proximity which can lead to high rates of transmission of viruses. Conversely, in large metropolitan cities in the west such as Los Angeles and London, large family-orientated gatherings are less common as dining space is more premium and the nature of city work doesn't permit such frequent activities. However, community behaviour in metropolitan areas is very different, individuals are exposed to a larger number of people to whom they are not related to. A study into the closeness of adolescents to their family found large discrepancies between countries in different regions, in Italy the family occupied a more central role, whilst in Canada, friends were shown to be more central (Claes, 1998). In countries where family-oriented life is more prevalent, it is often simple to map the spread of disease, contact tracing is therefore more difficult in metropolitan areas. In the Ebola outbreak of 2014, thorough contact tracing and subsequent quarantine of infected individuals led to the prompt eradication of the disease (Olu et al., 2016).

Culture and tradition can also provide behavioural cues that can increase the transmission of disease. Greetings are a common mode of social interaction which are seen universally in different manifestations. In North America and many parts of Europe, handshaking is a very common form of greeting that is used in professional settings as well as in other social situations. Shaking of hands is known to be able to transmit viable viruses person-to-person (Guarner, 2020; Rheinbaben et al., 2000). Social distancing may negate some of these contact behaviours, but others are more difficult to stop as they are embedded deep into tradition. For example, in countries such as Italy and Spain, greetings which involve kisses are very common, family and friends are greeted this way as a norm and these practices often go unnoticed to the individuals, whilst the proximity of such contact increases the risk of viral infections. These traditions however are not just confined to certain continents as they are common in many countries in South America, Europe and some Middle Eastern countries.

2.4 | International policies to prevent the spread of infection

As the most accepted and recognised form of transmission of the disease is through close contact with infected individuals, the United States Centre for Disease Control (US CDC) has advised people to keep a distance of at least 1.8 m from each other (CDC, 2020a). As the US CDC holds a lot of influence over the entire world, this measure is widely adopted in almost every country and can be referred to as the 2 m social distancing rule. However, many believe that 2 m is not an adequate distance to prevent the spread of infection. In a recent study into the aerosol and surface distribution of the SARS-CoV-2 virus in hospital wards, the aerosol distribution characteristics of the highly contagious virus showed signs that the transmission distance could be up to 4 m (Zhen-Dong et al., 2020).

Before the severity of COVID-19 was fully understood, many countries tried to suppress the spread of the virus with public awareness of the importance of washing their hands frequently throughout the day. Hands are a vector for viral transmission as they regularly touch infected surfaces; the average person touches their

nose and mouth over 20 times in an hour, leading to viral contamination (Kwok et al., 2015). Soap and alcohol-based hand sanitisers are highly effective in deactivating viruses by destroying their cell membrane and causing leakage of their contents (Grayson et al., 2009). North American and European countries such as the UK advise their residents to frequently wash their hands with soap and water for at least 20 s in order to kill the virus and reduce transmission (NHS, 2020b).

Wearing of facemasks in public has not yet been legally enforced in most countries worldwide. Until late May 2020, USA advised against community facemask use due to the negative impact it will have on the supplies to healthcare workers. However, the CDC is now advising people to wear a cloth face cover when in public (CDC, 2020b). The World Health Organization recommended facemasks to only those taking care of patients who have tested positive for COVID-19 and advises that healthy people need not wear such masks (WHO, 2020a). However, since 5 June 2020, the World Health Organization had begun to recommend face-covering in all public settings (WHO, 2020b).

Governments of countries such as the UK and Singapore had initially urged the public not to wear facemasks to ensure that valuable supplies for care workers were not being used up. Czech Republic was the first European country to mandate facemasks as early as March 18 2020, in just 10 days, almost the entirety of the population used masks made mostly from common household fabrics such as old t-shirts (Garcia, 2020). Slovakia, Bosnia and Herzegovina, Poland and Austria have also mandated public use of facemasks. In Africa, Morocco made public facemasks mandatory from April 7, 2020, the rule was heavily enforced and violation could result in a three-month prison sentence and a fine of about 130 US dollars.

Germany, a high-profile European Union country, made facemasks compulsory on public transport and during shopping in late April 2020. On 2 May 2020, Spain followed suit and made facemasks on public transport compulsory. However, influential nations such as USA, France and UK hesitated to mandate community facemask use due to the lack of evidence of its effectiveness and fear of supply shortages. The governor of New York, USA has ordered residents to wear masks in public. On 15 June 2020, a policy came into place that residents of the UK were to wear face coverings on public transport or not be allowed travel, this came as new guidance that face coverings should be worn in situations where social distancing is not feasible, such as in indoors places. Governments that have made the use of facemasks compulsory in public have not specified standards of facemasks to use, they merely stipulate the covering of the face and nose, the effectiveness of which against the transmission of viruses is unknown. Furthermore, there is no control over the re-usability of facemasks, non-adherence to procedures for the disposal of such masks may lead to a higher spread of the disease. On 28 June 2020, Iran announced the compulsory wearing of facemasks in public after dealing with a second peak in cases following no initial enforced lockdown or mask policy. As of 8 August 2020, the use of face coverings is mandatory in many indoor settings such as museums and places of worship in the United Kingdom.

3 | DATA ON THE USE OF FACEMASKS

3.1 | Comparing infection rates

There are many factors to consider when trying to determine how well a country responds to prevent the spread of infection. The virus testing protocols for the different countries are not equivalent: they differ drastically and are not correlated with their geographical or political standpoints. As countries take different approaches, there may be key elements in their protocols and policies that have reduced the number of infections and the number of subsequent deaths, this may well be the adherence to community facemask wearing. Figure 3 shows the weekly cases for the most affected countries from each affected continent.

The most affected country in the world, as of 21 June 2020, has been the USA. By far, this nation has the highest number of laboratory-confirmed cases and was the first country to have exceed a million cases. Adjusted for population size, the UK and USA (also the most affected countries in the world) have had their peaks at almost the same time (about 5 weeks after the 100th case), they also have had very similar behaviours regarding lockdown and facemask measures. We can also see that the earlier the lockdowns were placed, the less the cases rise (per million population) and sooner the first peaks appear. Brazil had a very late lockdown response (over 7 weeks after the 100th case) and therefore sees a very high increase in infections and cases per million. Currently, Brazil is on a very steep COVID-19 infection trajectory and is already amongst the highest number of cases per population of any country in the world. The socio-economics of Brazil put it unfavourably against the COVID-19 outbreak, the vast portion of its inhabitants are unable to access the necessary healthcare services to fight the disease. Furthermore, there may be less acceptance of lockdown measures as the population already faces danger from many other diseases and lockdown measures have a detrimental effect on their ability to provide families with food to survive. Additionally, millions will not be able to afford face masks, which could potentially increase the rate of infection.

The number of cases seen in the USA is alarmingly high, this could be due to how late the lockdown was enforced onto its population, allowing the virus to spread more widely through the population. The USA had no facemask policy before lockdown measures were announced, and as of August 10 2020, still have not mandated coverings completely onto its entire population. Countries such as the USA and the UK have exceptionally good transport links which see high daily footfall, therefore it can be expected that these countries see sharp spikes during the initial stage of a pandemic where the impact of mass travel follows the rapid distribution of the virus throughout the country's main transportation hub locations. Therefore developing modelling frameworks of facemask use, whilst being academically beneficial, are only effective at certain timepoints and are not universally applicable (Stutt et al., 2020).

At the epicentre of the pandemic, China has been the worst affected country in Asia, however, it has seen a large relative peak in its

4th week after the initial 100th case and has not seen a subsequent rise in the number of cases since. China has become the leading manufacturer of cloth facemasks and is responsible for the majority of global supplies, it also has a population which adheres strictly to the use of face masks (Wu et al., 2020). Compared to North America and Europe, the lockdown strategies in Wuhan, China, were thought to be much stricter, restricting the movement of individuals to a greater extent (Lu, 2020; Pulla, 2020). Another observation that could be made is the effect of temperature as a factor in the spread of disease. In the western hemisphere, at the time of the outbreak, temperatures were lower. In south Asia however, temperatures were much higher, which could have contributed to a reduction in the viability of the virus. South Korea and China, both in their winter stages, saw a large number of cases, similar to the trajectory of the early stages in Europe. Countries such as India, Singapore, Malaysia and Thailand, had very high temperatures during March 2020, the month which saw the steepest worldwide rise in cases.

Generally, we can see that the sooner the lockdown measures were enforced, the sooner the first peak arises with a lower number of cases per population. It can also be observed that the number of cases decreases rapidly, only after an initial peak has been formed, possibly indicating a natural limit for the spread of the virus. For example, South Africa had taken one of the earliest lockdown measures and has been able to keep a relatively low number of cases per population rate compared to other countries, however, it has not seen its first peak as compared to the other countries in the data, indicating that the measures have managed to suppress a peak in cases. However, it seems that South Africa too is on a trajectory for a rapid increase in cases, following a relatively slow initial rise. The data presented here suggest that lockdown measures are effective in reducing the spread of the disease, but as most countries initially chose to lockdown instead of applying a mask-only policy we cannot deduce the effect of a community facemask policy without taking into consideration the profound effects of lockdown and social distancing.

As mentioned before, most countries took to lockdown measures as the first resort against the spread of widespread infection for their residents as opposed to enforcing facemask laws. Figure 4 shows the logarithmic seven-day running average profiles for ten of the most affected countries which did not mandate public facemasks, the vertical blue line shows the relative date of lockdown measures. When movement restrictions are imposed, a change in the rate can be detected about ten days later. If facemasks are effective, then we expect to see a similar effect in a comparable time after mask-wearing is mandated. The time axis shows the number of days after the total number of cases for the country in question has exceeded 100. Daily cases are reported as a seven-day running average. Solid vertical lines show when movement restrictions were imposed. Logarithms of numbers of cases per million are used at the early stages of an epidemic, when cases rise exponentially. At the natural epicentre of the disease in China, strict lockdown measures saw a significant reduction in the number of cases following a peak in cases which was observed about 20 days following the first notable batch of cases. There is roughly a 10-day delay from when restrictions are enforced onto the public and to where there is a noticeable change in the number of cases, this is most likely due to the incubation period of COVID-19 which is typically around 7-10 days until symptoms start showing and tests would be carried out, for this reason UK was considered a country where facemasks had not yet been mandated (Lauer et al., 2020; Singhal, 2020). Comparable plots of the numbers of deaths show peaks after about 20 days. Countries which had their lockdowns enforced around the same relative time such as the USA, UK and Italy, see peaks in cases at around the 30th day. Interestingly, these three countries are also amongst the most affected in the world, which could potentially suggest that the virus may give an initial natural peak about 30 days from the first notable infection when social distancing measures are put into place. Iran and South Korea, the two countries on the list with no formal restriction of movement, do not see the same profile in the number of cases as is observed with countries that have imposed these measures. Therefore, the reduction in the number of cases in these countries will be down to other key factors such as efficient testing and isolating, general public facemask adherence and public awareness of localised outbreaks (such as a track and trace system). South Korea has been known to have world-leading testing and contact tracing systems, typically follows a high adherence to public facemask wearing typical of east Asian countries and also has a public government-backed alert system for COVID-19 cases (Park, Choi, et al., 2020; Park, Kim, et al., 2020; Salathé et al., 2020).

It can also be noted from Figure 4 that there are two countries which did not officially enforce a public lockdown, these countries are Iran and South Korea. However, South Korea has seen a large number of cases during previous pandemics and as such, the government and the public are more prepared, general acceptance of facemask adherence as well as world-leading track and trace systems have led to the containment of the virus. Conversely, if we look at Iran, there was no official country-wide lockdown or need for facemasks. As such, the country is in the beginning of a second rise in infection rates as the daily totals have increased following the first peak (Strzelecki, 2020). This second rise in infections could outgrow the first and is an indication that social distancing measures, through the use of enforced lockdowns, do aid to reduce the infection rate of the virus.

Some ten countries with large numbers of COVID-19 cases have mandated the community use of facemasks about a couple of weeks after lockdown measures, with the intention to further reduce the spread of disease in their populations. Figure 5 shows the log profiles in their case numbers, the blue vertical line marks lockdown measures and the dotted line indicates the date of facemask policy. We can see that there is a falloff in cases following 10 days from lockdown dates, this is due to the virus being able to come into contact with fewer people as they isolate and reduce social contact. Morocco, which did not have a complete lockdown policy does not see a rise in cases typical as other countries which did, this could indicate that the peak of cases has not been met within the timeframe of the data. When we compare the profiles of all the countries which

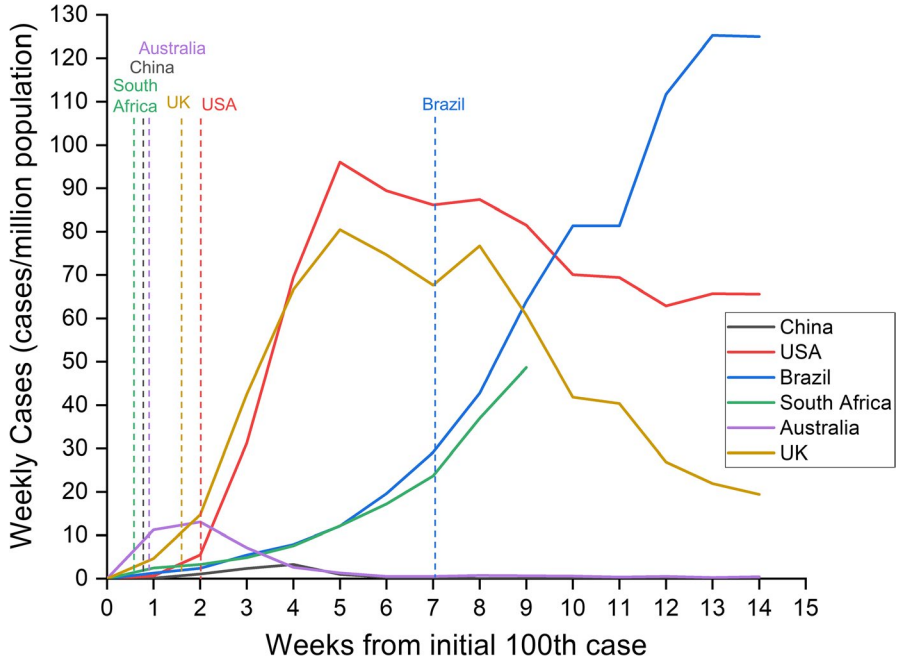

FIGURE 3 Graph showing the average weekly cases in the most affected countries from each continent, the relative lockdown dates from the 100th recorded case are colour-coded and labelled. Data obtained from the ECDC publicly available database (ECDC, 2020)

did eventually mandate facemasks, the reduction in the number of cases is in-line with the expected projection of cases resulting from movement restrictions and social distancing. If facemask wearing were to significantly decrease the number of infections, we would expect a greater fall in numbers. In most cases, the insistence on facemasks was introduced at the same time as some relaxation of restrictions on travel and assembly, but there is no reliable way of accounting for those changes. Overall, we would interpret this as suggesting that the wearing of facemasks reduced the spread of the pandemic, but to an extent that we cannot quantify. We note that a recent meta-survey concluded that facemasks had a significant effect in reducing the spread of infection, but that the certainty of the evidence was low (Chu et al., 2020).

There are many factors to consider which can contribute to the spread of disease. Firstly, testing methodologies differ widely from country to country; the numbers publicly provided globally may not represent the total number of actual cases in a country. In trying to discern the effect of facemasks on the rate of infection, healthcare practices, socio-economics, lifestyle, the effect of lockdown and many other key features must be accounted for. From the data presented, we cannot conclusively deduce that facemasks reduce the spread of infection; however, countries which did not mandate facemasks have not seen significant deviation in the case profiles. The data therefore suggest that lockdown measures have a clearly visible effect in the management of a pandemic, but the evidence for the effect of facemasks is much weaker. It is important to note that behavioural changes could be observed following the initial spread of the disease by late February, as people understood the severity of the pandemic and anticipated movement restrictions. Although we draw sharp lines on our graphs to mark when restrictions were legally imposed, in most cases the public's behaviour had started to change several days or months before official lockdown or facemask policies were enforced.

3.2 | Dangers in advising community facemask wearing

One of the issues relating to the constant use of facemasks and higher than normal disinfection of surfaces and hands is the risk that it poses to the human immune system. The immune system is a highly complex system of cells and signals which is ever developing, its potency reduces with age and is also thought to be affected by a reduced exposure to a variety of microbes. It is found that exposure to various microbes at the developing stages of human life has positive effects on the T cell function of the immune system which can persist into adult life and beyond (Kelly et al., 2007; Olszak et al., 2012). Therefore, the immune system is highly adaptive, constantly learning and developing; to reduce exposure to the multitude of 'normal microbes' present in the environment via the use of facemasks and disinfection, can lead to the decreased efficiency caused by 'undertrained immune cells'. The overuse of disinfection and hand sanitation leads to the destruction of bacteria and other microbes that may have a symbiotic relationship with the skin and the normal function of the immune system (Gallo & Nakatsuji, 2011). The immune system may quickly adapt to the new conditions that lockdown imposes, such as physical isolation, covering of external respiratory system and disinfection. Following these restrictions, it may cause individuals to become overly susceptible to immune system attacks from bacteria and viruses, not being limited to just COVID-19.

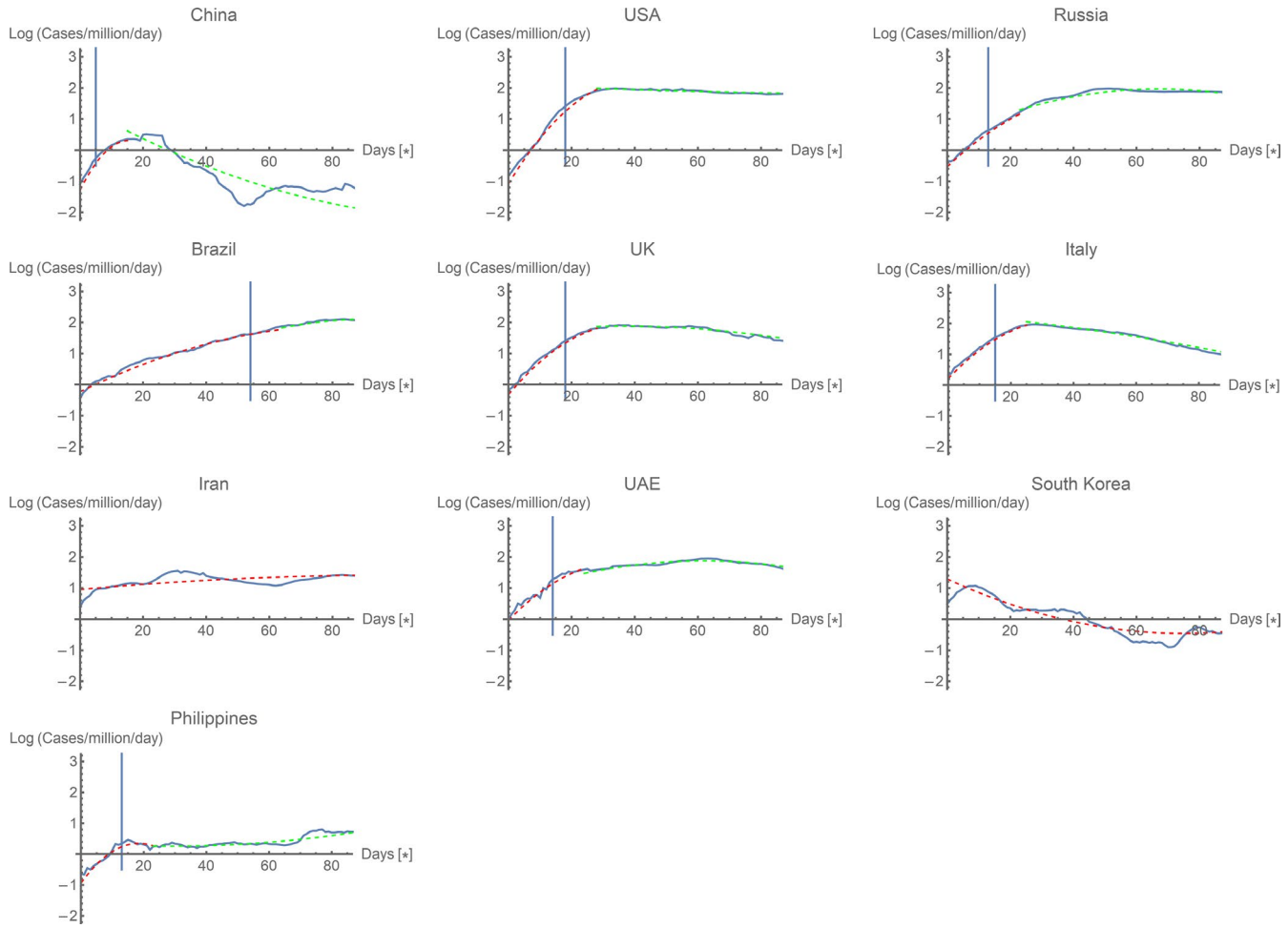

FIGURE 4 Daily data for countries which did not initially mandate facemasks. The blue lines show the reported data, red dashed lines are three-parameter fit smooth curves fitted from day 1 up to 10 days after the imposition of movement restrictions (or to all the data where there were no movement restrictions), and green dashed curves are a three-parameter fit to the remainder of the data. Data obtained from the ECDC publicly available database (ECDC, 2020)

As the exterior of the masks is exposed to the environment, the pressure differential between the respiratory tract and the mask cause virus particles to be lodged onto the outside of the mask. This creates a high concentration of viruses at the exposed end of the mask, which can be subsequently touched inadvertently. Because the concentration of virus is so high at these points, this can lead to an increased chance of infection for the wearer or people in proximity. Facemasks can also lull the wearer into a false sense of security which may see them take risks which they may not otherwise have taken without the protection of a facemask. As there is no scientific evidence to suggest that facemasks are a complete barrier to respiratory infections, the public perception that facemasks may stop infections could be dangerous.

Another potential issue with the large-scale use of facemasks is the logistical problem we will face in the disposal of face masks. Polymers such as polypropylene can take over 20 years to completely decompose in landfills, causing environmental concerns to wildlife and air quality. As polymers are a necessary class of materials that are required in healthcare for sterilisation reasons, the public view on plastics after the epidemic may be so negative that it will influence a decline in its use in healthcare industry (Czigany & Ronkay, 2020). Furthermore, the short-term disposal of the masks could create a selection pressure for viral growth that may see a rise in serious mutations, similar to what we see with bacteria and other viruses (Banke et al., 2009; Bartholomeusz & Locarnini, 2006). If masks were to be disposed of in bins for example, the viruses still present on them would eventually die with no host present, but a few remaining viruses will naturally be more resilient. With the improper disposal of masks, there may be a higher concentration of resilient viruses that can subsequently infect individuals who are not careful with waste systems.

Furthermore, if facemasks where to be mandated, there would be no policing or standard behind the level of protection users may have. For example, a facemask may be a basic cloth mask all the way up to an N99 mask which offers maximal protection. Members of the population with a lower income may not be able to regularly acquire effective cloth material and thus will be exposed to the virus at a greater extent, putting both themselves and other members of the public at higher risk.

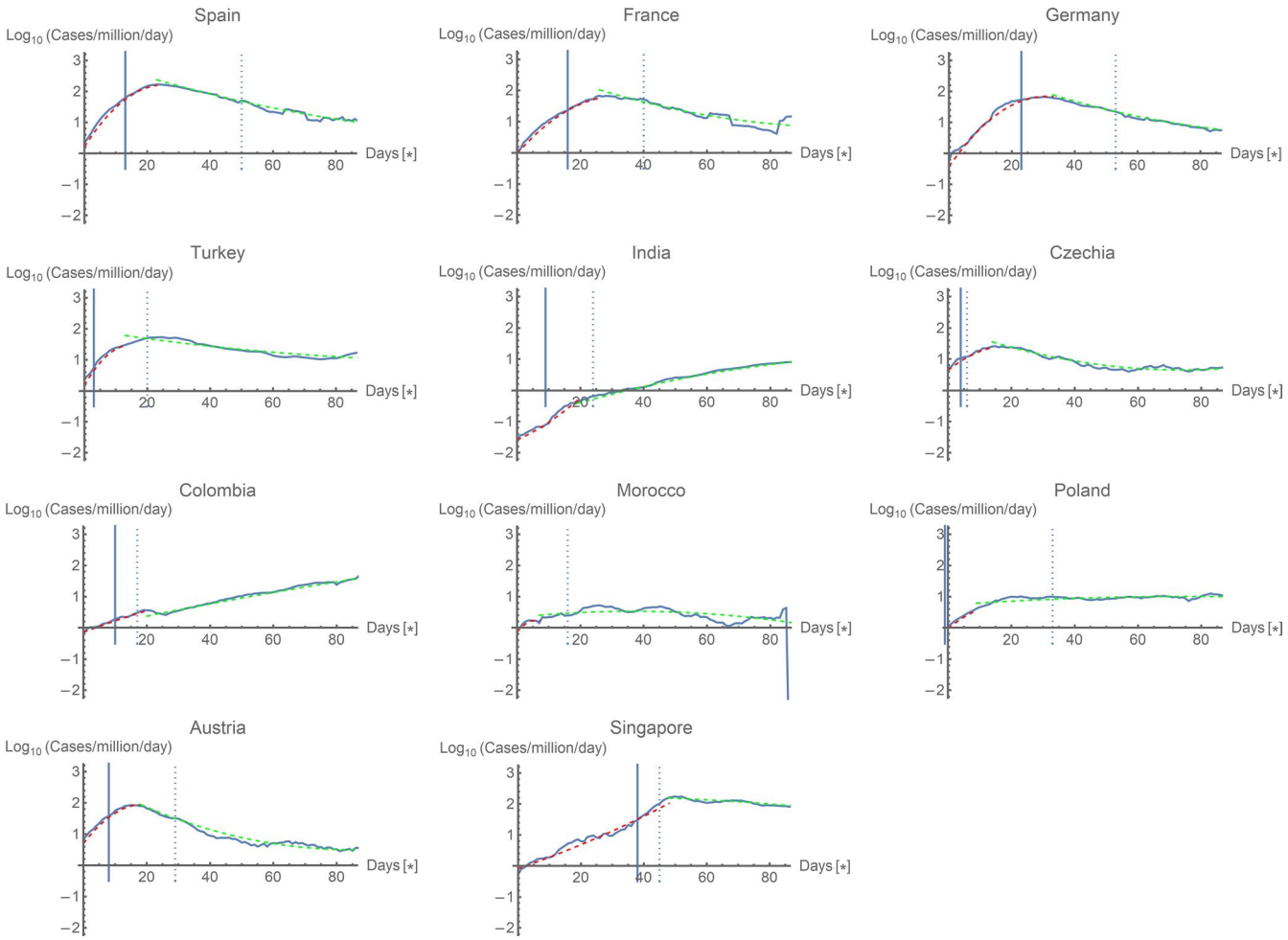

FIGURE 5 Daily data for countries which did mandate facemasks. The blue lines show the reported data, red dashed lines are three-parameter smooth curves fitted from day 1 up to 10 days after the imposition of movement restrictions, and green dashed curves are a three-parameter fit to the remainder of the data. Data obtained from the ECDC publicly available database (ECDC, 2020)

4 | CONCLUSIONS

Facemasks are routinely used by healthcare workers to prevent the entry of droplets into their respiratory tract, it is therefore reasonable to expect that the use of such masks will have a positive effect in the prevention of transmission. As the disease is known to spread via asymptomatic carriers, the wearing of facemasks may help to reduce the spread of the disease. However, the effectiveness of facemasks differs greatly with the complexity of the mask material, air-tight seal and adherence to keeping it worn. Therefore, we cannot say that mandating facemasks will have a profound positive effect in the reduction of the spread. This depends more on the public's awareness of how disease spreads, to maintain distance from infectious aerosols, to wear facemasks for the entire duration of public exposure, to dispose of masks without touching the exterior and to maintain a full seal at all times.

When epidemics begin, we always seem to see a high demand for facemasks which exacerbates the global supply shortage and increases pricing. This can have an adverse effect on the transmission of the disease and the local economy. If there is a shortage of supply of face masks to healthcare settings, the spread can be worsened in the long run as nurses and doctors get infected and can no longer treat the infected. In conclusion, from the data shown, there is no conclusive evidence that facemasks themselves significantly reduce the spread of infection; however, there is evidence to strongly suggest that social distancing measures reduce infection rates. Many important factors work together to determine the spread of infectious diseases. There is therefore no evidence to suggest that facemasks worsen the spread and thus the wearing of facemasks can perhaps be a supplementary mode of action to reduce disease spread following the initial peak of a pandemic when the infection rate is lower.

ACKNOWLEDGEMENTS

The authors would like to that the Royal Academy of Engineering for seedcorn funding this work over the last three months.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interests.

REFERENCES

Aitken, M. L., Limaye, A., Pottinger, P., Whimbey, E., Goss, C. H., Tonelli, M. R., & Wallace, R. J. (2012). Respiratory Outbreak of *Mycobacterium abscessus* subspecies *massiliense* in a Lung Transplant and Cystic Fibrosis Center. *American Journal of Respiratory and Critical Care Medicine*, *185*(2), 231–232. https://doi.org/10.1164/ajrccm.185.2.231

Alenezi, H., Cam, M. E., & Edirisinghe, M. (2019). Experimental and theoretical investigation of the fluid behavior during polymeric fiber formation with and without pressure. *Applied Physics Reviews*, *6*(4), 041401. https://doi.org/10.1063/1.5110965

Alraddadi, B. M., Watson, J. T., Almarashi, A., Abedi, G. R., Turkistani, A., Sadran, M., Housa, A., Almazroa, M. A., Alraihan, N., Banjar, A., Albalawi, E., Alhindi, H., Choudhry, A. J., Meiman, J. G., Paczkowski, M., Curns, A., Mounts, A., Feikin, D. R., Marano, N., & Madani, T. A. (2016). Risk factors for primary middle east respiratory syndrome coronavirus illness in humans, Saudi Arabia, 2014. *Emerging Infectious Diseases*, *22*(1), 49–55. https://doi.org/10.3201/eid2201.151340

Antunes, M. B., & Cohen, N. A. (2007). Mucociliary clearance–a critical upper airway host defense mechanism and methods of assessment. *Current Opinion in Allergy and Clinical Immunology*, *7*(1), 5–10. https://doi.org/10.1097/ACI.0b013e3280114eef

Bae, S., Kim, M.-C., Kim, J. Y., Cha, H.-H., Lim, J. S., Jung, J., Kim, M.-J., Oh, D. K., Lee, M.-K., Choi, S.-H., Sung, M., Hong, S.-B., Chung, J.-W., & Kim, S.-H. (2020). Effectiveness of surgical and cotton masks in blocking SARS–CoV-2: A controlled comparison in 4 patients. *Annals of Internal Medicine*, *173*(1), W22–W23. https://doi.org/10.7326/M20-1342

Baetjer, A. M. (1967). Effect of ambient temperature and vapor pressure on cilia-mucus clearance rate. *Journal of Applied Physiology*, *23*(4), 498–504. https://doi.org/10.1152/jappl.1967.23.4.498

Balazy, A., Toivola, M., Reponen, T., PodgÓRski, A., Zimmer, A., & Grinshpun, S. A. (2005). Manikin-based performance evaluation of N95 filtering-facepiece respirators challenged with nanoparticles. *Annals of Occupational Hygiene*, *50*(3), 259–269. https://doi.org/10.1093/annhyg/mei058

Balcan, D., Colizza, V., Gonçalves, B., Hu, H., Ramasco, J. J., & Vespignani, A. (2009). Multiscale mobility networks and the spatial spreading of infectious diseases. *Proceedings of the National Academy of Sciences of the United States of America*, *106*(51), 21484–21489. https://doi.org/10.1073/pnas.0906910106

Banke, S., Lillemark, M. R., Gerstoft, J., Obel, N., & Jørgensen, L. B. (2009). Positive selection pressure introduces secondary mutations at gag cleavage sites in human immunodeficiency virus type 1 harboring major protease resistance mutations. *Journal of Virology*, *83*(17), 8916. https://doi.org/10.1128/JVI.00003-09

Bartholomeusz, A., & Locarnini, S. (2006). Hepatitis B virus mutations associated with antiviral therapy. *Journal of Medical Virology*, *78*(S1), S52–S55. https://doi.org/10.1002/jmv.20608

Belkin, N. L. (1996). A century after their introduction, are surgical masks necessary? *AORN Journal*, *64*(4), 602–607. https://doi.org/10.1016/S0001-2092(06)63628-4

Bhaskar, M. E., & Arun, S. (2020). SARS-CoV-2 Infection Among Community Health Workers in India Before and After Use of Face Shields. *JAMA*. https://doi.org/10.1001/jama.2020.15586

Brown, C. K. (2019). Respiratory protection against emerging infectious diseases: Face masks, respirators, and tools for choosing between them. *Health Security*, *17*(2), 133–139. https://doi.org/10.1089/hs.2018.0056

Brownstein, J. S., Pena, B. G., & Mandl, K. D. (2007). Characterizing socioeconomic disparities in the burden of influenza and RSV using surveillance data. *Advances in Disease Surveillance*, *2*, 94.

Brunner, J., Zugliani, C., & Mischler, R. (1991). Fusion activity of influenza virus PR8/34 correlates with a temperature-induced conformational change within the hemagglutinin ectodomain detected by photochemical labeling. *Biochemistry*, *30*(9), 2432–2438. https://doi.org/10.1021/bi00223a019

Casanova, L. M., Jeon, S., Rutala, W. A., Weber, D. J., & Sobsey, M. D. (2010). Effects of air temperature and relative humidity on coronavirus survival on surfaces. *Applied and Environmental Microbiology*, *76*(9), 2712–2717. https://doi.org/10.1128/AEM.02291-09

CDC (2020a, 19/04/2020). *Coronavirus Disease 2019 social distancing, quarantine, and isolation*. Retrieved from https://www.cdc.gov/coronavirus/2019-ncov/

CDC (2020b, 02/05/2020). *How to protect yourself & others. Coronavirus disease 2019 (COVID-19)*. Retrieved from https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/prevention.html

Chan, W. M., Yuen, K. S. C., Fan, D. S. P., Lam, D. S. C., Chan, P. K. S., & Sung, J. J. Y. (2004). Tears and conjunctival scrapings for coronavirus in patients with SARS. *British Journal of Ophthalmology*, *88*(7), 968–969. https://doi.org/10.1136/bjo.2003.039461

Chen, S.-K., Vesley, D., Brosseau, L. M., & Vincent, J. H. (1994). Evaluation of single-use masks and respirators for protection of health care workers against mycobacterial aerosols. *American Journal of Infection Control*, *22*(2), 65–74. https://doi.org/10.1016/0196-6553(94)90116-3

Chu, D. K., Akl, E. A., Duda, S., Solo, K., Yaacoub, S., Schünemann, H. J., Chu, D. K., Akl, E. A., El-harakeh, A., Bognanni, A., Lotfi, T., Loeb, M., Hajizadeh, A., Bak, A., Izcovich, A., Cuello-Garcia, C. A., Chen, C., Harris, D. J., Borowiack, E., & Schünemann, H. J. (2020). 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*, *395*(10242), 1973–1987. https://doi.org/10.1016/S0140-6736(20)31142-9

Claes, M. (1998). Adolescents' closeness with parents, siblings, and friends in three countries: Canada, Belgium, and Italy. *Journal of Youth and Adolescence*, *27*(2), 165–184. https://doi.org/10.1023/A:1021611728880

Cummins, C. P., Ajayi, O. J., Mehendale, F. V., Gabl, R., & Viola, I. M. (2020). The dispersion of spherical droplets in source–sink flows and their relevance to the COVID-19 pandemic. *Physics of Fluids*, *32*(8), 083302. https://doi.org/10.1063/5.0021427

Czigany, T., & Ronkay, F. (2020). The coronavirus and plastics. *Express Polymer Letters*, *14*, 510–511. https://doi.org/10.3144/expresspolymlett.2020.41

Davidson, C. I., Phalen, R. F., & Solomon, P. A. (2005). Airborne particulate matter and human health: A review. *Aerosol Science and Technology*, *39*(8), 737–749. https://doi.org/10.1080/02786820500191348

Davies, A., Thompson, K.-A., Giri, K., Kafatos, G., Walker, J., & Bennett, A. (2013). Testing the efficacy of homemade masks: Would they protect in an influenza pandemic? *Disaster Medicine and Public Health Preparedness*, *7*(4), 413–418. https://doi.org/10.1017/dmp.2013.43

Derrick, J. L., & Gomersall, C. D. (2004). Surgical helmets and SARS infection. *Emerging Infectious Diseases*, *10*(2), 277–279. https://doi.org/10.3201/eid1002.030764

Dunn, J. R. (2002). Housing and inequalities in health: a study of socioeconomic dimensions of housing and self reported health from a survey of Vancouver residents. *Journal of Epidemiology and Community Health*, *56*(9), 671–681. https://doi.org/10.1136/jech.56.9.671

ECDC (2020). *COVID-19 situation update worldwide*. Retrieved from https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases

Elachola, H., Ebrahim, S. H., & Gozzer, E. (2020). COVID-19: Facemask use prevalence in international airports in Asia, Europe and the Americas, March 2020. *Travel Medicine and Infectious Disease*, *35*, 101637. https://doi.org/10.1016/j.tmaid.2020.101637

Feng, S., Shen, C., Xia, N., Song, W., Fan, M., & Cowling, B. J. (2020). Rational use of face masks in the COVID-19 pandemic. *Lancet*

Respiratory Medicine, *8*(5), 434–436. https://doi.org/10.1016/S2213-2600(20)30134-X

Fernstrom, A., & Goldblatt, M. (2013). Aerobiology and its role in the transmission of infectious diseases. *Journal of Pathogens*, *2013*, 493960. https://doi.org/10.1155/2013/493960

FMH (2020, 13/04/2020). *Daily updates on the coronavirus: is wearing a surgical mask, as protection against acute respiratory infections, useful for members of the general public?* Retrieved from https://www.bundesgesundheitsministerium.de/en/press/2020/coronavirus.html

Gallo, R. L., & Nakatsuji, T. (2011). Microbial symbiosis with the innate immune defense system of the skin. *Journal of Investigative Dermatology*, *131*(10), 1974–1980. https://doi.org/10.1038/jid.2011.182

Garcia, L. P. (2020). Use of facemasks to limit COVID-19 transmission. *Epidemiology and Health Services*, *29*(2), 1–4. https://doi.org/10.5123/S1679-49742020000200021

Gawn, J., Clayton, M., Makison, C., & Crook, B. (2008). *Evaluating the protection afforded by surgical masks against influenza bioaerosols: gross protection of surgical masks compared to filtering facepiece respirators*. Retrieved from http://europepmc.org/abstract/CTX/C3304

Goldsmith, C. S., Tatti, K. M., Ksiazek, T. G., Rollin, P. E., Comer, J. A., Lee, W. W., Rota, P. A., Bankamp, B., Bellini, W. J., & Zaki, S. R. (2004). Ultrastructural characterization of SARS coronavirus. *Emerging Infectious Diseases*, *10*(2), 320–326. https://doi.org/10.3201/eid1002.030913

Grayson, M. L., Melvani, S., Druce, J., Barr, I. G., Ballard, S. A., Johnson, P. D. R., Mastorakos, T., & Birch, C. (2009). Efficacy of soap and water and alcohol-based hand-rub preparations against live H1N1 Influenza virus on the hands of human volunteers. *Clinical Infectious Diseases*, *48*(3), 285–291. https://doi.org/10.1086/595845

Grinshpun, S. A., Haruta, H., Eninger, R. M., Reponen, T., McKay, R. T., & Lee, S.-A. (2009). Performance of an N95 filtering facepiece particulate respirator and a surgical mask during human breathing: Two pathways for particle penetration. *Journal of Occupational and Environmental Hygiene*, *6*(10), 593–603. https://doi.org/10.1080/15459620903120086

Guarner, J. (2020). Three emerging coronaviruses in two decades: The story of SARS, MERS, and Now COVID-19. *American Journal of Clinical Pathology*, *153*(4), 420–421. https://doi.org/10.1093/ajcp/aqaa029

Harper, G. J. (1961). Airborne micro-organisms: Survival tests with four viruses. *Journal of Hygiene*, *59*(4), 479–486. https://doi.org/10.1017/s0022172400039176

Hemmes, J. H., Winkler, K. C., & Kool, S. M. (1960). Virus survival as a seasonal factor in influenza and poliomyelitis. *Nature*, *188*(4748), 430–431. https://doi.org/10.1038/188430a0

Heseltine, P. L., Ahmed, J., & Edirisinghe, M. (2018). Developments in pressurized gyration for the mass production of polymeric fibers. *Macromolecular Materials and Engineering*, *303*(9), 1800218. https://doi.org/10.1002/mame.201800218

Hong, X., Harker, A., & Edirisinghe, M. (2019). Empirical modelling and optimization of pressure-coupled infusion gyration parameters for the nanofibre fabrication. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *475*(2225), 20190008. https://doi.org/10.1098/rspa.2019.0008

Hood, A. M. (1963). Infectivity of influenza virus aerosols. *Journal of Hygiene*, *61*, 331–335. https://doi.org/10.1017/s0022172400039619

Jianyun, L., Jieni, G., Kuibiao, L., Conghui, X., Wenzhe, S., Zhisheng, L., & Zhicong, Y. (2020). COVID-19 outbreak associated with air conditioning in restaurant, Guangzhou, China, 2020. *Emerging Infectious Diseases*, *26*(7), 1628–1631. https://doi.org/10.3201/eid2607.200764

Johnson, D. F., Druce, J. D., Birch, C., & Grayson, M. L. (2009). A quantitative assessment of the efficacy of surgical and N95 masks to filter influenza virus in patients with acute influenza infection. *Clinical Infectious Diseases*, *49*(2), 275–277. https://doi.org/10.1086/600041

Kelly, D., King, T., & Aminov, R. (2007). Importance of microbial colonization of the gut in early life to the development of immunity. *Mutation Research/Fundamental and Molecular Mechanisms of Mutagenesis*, *622*(1), 58–69. https://doi.org/10.1016/j.mrfmmm.2007.03.011

Kenessey, Z. (1987). The primary, secondary, tertiary and quaternary sectors of the economy. *Review of Income and Wealth*, *33*(4), 359–385. https://doi.org/10.1111/j.1475-4991.1987.tb00680.x

Knight, V. (1980). Viruses as agents of airborne contagion. *Annals of the New York Academy of Sciences*, *353*, 147–156. https://doi.org/10.1111/j.1749-6632.1980.tb18917.x

Kwok, Y. L., Gralton, J., & McLaws, M. L. (2015). Face touching: A frequent habit that has implications for hand hygiene. *American Journal of Infection Control*, *43*(2), 112–114. https://doi.org/10.1016/j.ajic.2014.10.015

Lai, C.-C., Shih, T.-P., Ko, W.-C., Tang, H.-J., & Hsueh, P.-R. (2020). Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and coronavirus disease-2019 (COVID-19): The epidemic and the challenges. *International Journal of Antimicrobial Agents*, *55*(3), 105924. https://doi.org/10.1016/j.ijantimicag.2020.105924

Lau, J. T. F., Yang, X., Pang, E., Tsui, H. Y., Wong, E., & Wing, Y. K. (2005). SARS-related perceptions in Hong Kong. *Emerging Infectious Diseases*, *11*(3), 417–424. https://doi.org/10.3201/eid1103.040675

Lauer, S. A., Grantz, K. H., Bi, Q., Jones, F. K., Zheng, Q., Meredith, H. R., Azman, A. S., Reich, N. G., & Lessler, J. (2020). The incubation period of coronavirus disease 2019 (COVID-19) from publicly reported confirmed cases: Estimation and application. *Annals of Internal Medicine*, *172*(9), 577–582. https://doi.org/10.7326/M20-0504

Lee, K. W., & Liu, B. Y. H. (1982). Theoretical study of aerosol filtration by fibrous filters. *Aerosol Science and Technology*, *1*(2), 147–161. https://doi.org/10.1080/02786828208958584

Lee, M.-R., Sheng, W.-H., Hung, C.-C., Yu, C.-J., Lee, L.-N., & Hsueh, P.-R. (2015). *Mycobacterium abscessus* complex infections in humans. *Emerging Infectious Diseases*, *21*(9), 1638–1646. https://doi.org/10.3201/2109.141634

Lemieux, C., Brankston, G., Gitterman, L., Hirji, Z., & Gardam, M. (2007). Questioning aerosol transmission of influenza. *Emerging Infectious Diseases*, *13*(1), 173–175. https://doi.org/10.3201/eid1301.061202

Leonas, K., & Jones, C. (2003). The relationship of fabric properties and bacterial filtration efficiency for selected surgical face masks. *Journal of Textile and Apparel, Technology and Management*, *3*(2), 1-8.

Leung, W. W. F., & Sun, Q. (2020). Electrostatic charged nanofiber filter for filtering airborne novel coronavirus (COVID-19) and nano-aerosols. *Separation and Purification Technology*, *250*, 116886, https://doi.org/10.1016/j.seppur.2020.116886

Li, Y., Wong, T., Chung, J., Guo, Y. P., Hu, J. Y., Guan, Y. T., Yao, L., Song, Q. W., & Newton, E. (2006). In vivo protective performance of N95 respirator and surgical facemask. *American Journal of Industrial Medicine*, *49*(12), 1056–1065. https://doi.org/10.1002/ajim.20395

Li, Y., Yin, X., Yu, J., & Ding, B. (2019). Electrospun nanofibers for high-performance air filtration. *Composites Communications*, *15*, 6–19. https://doi.org/10.1016/j.coco.2019.06.003

Liang, M., Gao, L., Cheng, C., Zhou, Q., Uy, J. P., Heiner, K., & Sun, C. (2020). Efficacy of face mask in preventing respiratory virus transmission: A systematic review and meta-analysis. *Travel Medicine and Infectious Disease*, *36*, 101751. https://doi.org/10.1016/j.tmaid.2020.101751

Linacre, E. T. (1977). A simple formula for estimating evaporation rates in various climates, using temperature data alone. *Agricultural Meteorology*, *18*(6), 409–424. https://doi.org/10.1016/0002-1571(77)90007-3

Lindtner, S., Greenspan, A., & Li, D. (2015). *Designed in Shenzhen: Shanzhai manufacturing and maker entrepreneurs*. Paper Presented at the Proceedings of the Fifth Decennial Aarhus Conference on Critical Alternatives, Aarhus, Denmark.

Lo, J. Y., Tsang, T. H., Leung, Y. H., Yeung, E. Y., Wu, T., & Lim, W. W. (2005). Respiratory infections during SARS outbreak, Hong Kong, 2003. *Emerging Infectious Diseases*, *11*(11), 1738–1741. https://doi.org/10.3201/eid1111.050729

Loeb, M., Dafoe, N., Mahony, J., John, M., Sarabia, A., Glavin, V., Webby, R., Smieja, M., Earn, D. J. D., Chong, S., Webb, A., & Walter, S. D. (2009). Surgical mask vs N95 respirator for preventing influenza among health care workers: A randomized trial. *JAMA*, *302*(17), 1865–1871. https://doi.org/10.1001/jama.2009.1466

Loon, S. C., Teoh, S. C., Oon, L. L., Se-Thoe, S. Y., Ling, A. E., Leo, Y. S., & Leong, H. N. (2004). The severe acute respiratory syndrome coronavirus in tears. *British Journal of Ophthalmology*, *88*(7), 861–863. https://doi.org/10.1136/bjo.2003.035931

Loosli, C. G., Lemon, H. M., Robertson, O. H., & Appel, E. (1943). Experimental air-borne influenza infection. I. Influence of humidity on survival of virus in air. *Proceedings of the Society for Experimental Biology and Medicine*, *53*(2), 205–206. https://doi.org/10.3181/00379727-53-14251P

Lowen, A. C., Mubareka, S., Steel, J., & Palese, P. (2007). Influenza virus transmission is dependent on relative humidity and temperature. *PLoS Path*, *3*(10), e151. https://doi.org/10.1371/journal.ppat.0030151

Lowen, A. C., Steel, J., Mubareka, S., & Palese, P. (2008). High temperature (30 degrees C) blocks aerosol but not contact transmission of influenza virus. *Journal of Virology*, *82*(11), 5650–5652. https://doi.org/10.1128/JVI.00325-08

Lu, D. (2020). Inside Wuhan's lockdown. *New Scientist*, *245*(3268), 7. https://doi.org/10.1016/S0262-4079(20)30234-7

MacIntyre, C. R., Cauchemez, S., Dwyer, D. E., Seale, H., Cheung, P., Browne, G., & Ferguson, N. (2009). Face mask use and control of respiratory virus transmission in households. *Emerging Infectious Diseases*, *15*(2), 233–241. https://doi.org/10.3201/eid1502.081167

Mäkinen, T. M., Juvonen, R., Jokelainen, J., Harju, T. H., Peitso, A., Bloigu, A., & Hassi, J. (2009). Cold temperature and low humidity are associated with increased occurrence of respiratory tract infections. *Respiratory Medicine*, *103*(3), 456–462. https://doi.org/10.1016/j.rmed.2008.09.011

Mashreky, S. R., Rahman, A., Chowdhury, S. M., Svanström, L., Shafinaz, S., Khan, T. F., & Rahman, F. (2010). Health seeking behaviour of parents of burned children in Bangladesh is related to family socioeconomics. *Injury*, *41*(5), 528–532. https://doi.org/10.1016/j.injury.2009.05.017

MOH (2020). *Updates on Covid-19 (Coronavirus disease 2019) local situation*. Retrieved from https://www.moh.gov.sg/covid-19

Molnar, K., & Meszaros, L. (2020). The role of electrospun nanofibers in the fight against the COVID-19. *Express Polymer Letters*, *14*, 605. https://doi.org/10.3144/expresspolymlett.2020.49

Nasir, Z. A., Campos, L. C., Christie, N., & Colbeck, I. (2016). Airborne biological hazards and urban transport infrastructure: current challenges and future directions. *Environmental Science and Pollution Research*, *23*(15), 15757–15766. https://doi.org/10.1007/s11356-016-7064-8

NHS (2020a, 13/04/2020). *Are face masks useful for preventing coronavirus?* Retrieved from https://www.nhs.uk/conditions/coronavirus-covid-19/common-questions/

NHS (2020b). *How to wash your hands. Coronavirus (COVID-19)*. Retrieved from https://www.nhs.uk/live-well/healthy-body/best-way-to-wash-your-hands/

Nicas, M., Nazaroff, W. W., & Hubbard, A. (2005). Toward understanding the risk of secondary airborne infection: emission of respirable pathogens. *Journal of Occupational and Environmental Hygiene*, *2*(3), 143–154. https://doi.org/10.1080/15459620590918466

Nicholson, K. G. (1996). Socioeconomics of influenza and influenza vaccination in Europe. *Pharmacoeconomics*, *9*(3), 75–78. https://doi.org/10.2165/00019053-199600093-00017

Olszak, T., An, D., Zeissig, S., Vera, M. P., Richter, J., Franke, A., Glickman, J. N., Siebert, R., Baron, R. M., Kasper, D. L., & Blumberg, R. S. (2012). Microbial exposure during early life has persistent effects on natural killer T cell function. *Science*, *336*(6080), 489–493. https://doi.org/10.1126/science.1219328

Olu, O. O., Lamunu, M., Nanyunja, M., Dafae, F., Samba, T., Sempiira, N., Kuti-George, F., Abebe, F. Z., Sensasi, B., Chimbaru, A., Ganda, L., Gausi, K., Gilroy, S., & Mugume, J. (2016). Contact tracing during an outbreak of Ebola virus disease in the western area districts of Sierra Leone: Lessons for future Ebola outbreak response. *Frontiers in Public Health*, *4*, 130. https://doi.org/10.3389/fpubh.2016.00130

Park, S., Choi, G. J., & Ko, H. (2020). Information technology-based tracing strategy in response to COVID-19 in South Korea—Privacy controversies. *JAMA*, *323*(21), 2129–2130. https://doi.org/10.1001/jama.2020.6602

Park, S. Y., Kim, Y.-M., Yi, S., Lee, S., Na, B.-J., Kim, C. B., Kim, J.-I., Kim, H. S., Kim, Y. B., Park, Y., Huh, I. S., Kim, H. K., Yoon, H. J., Jang, H., Kim, K., Chang, Y., Kim, I., Lee, H., Gwack, J., & Jeong, E. K. (2020). Coronavirus disease outbreak in call center, South Korea. *Emerging Infectious Diseases*, *26*(8), 1666–1670. https://doi.org/10.3201/eid2608.201274

Peiris, J., Chu, C. M., Cheng, V., Chan, K. S., Hung, I., Poon, L., Law, K. I., Tang, B., Hon, T., Chan, C. S., Chan, K. H., Ng, J., Zheng, B. J., Ng, W. L., Lai, R., Guan, Y., & Yuen, K. Y. (2003). Clinical progression and viral load in a community outbreak of coronavirus-associated SARS pneumonia: a prospective study. *Lancet*, *361*(9371), 1767–1772. https://doi.org/10.1016/s0140-6736(03)13412-5

Pirtle, E., & Beran, G. (1991). Virus survival in the environment. *Revue Scientifique Et Technique*, *10*(3), 733–748.

Pulla, P. (2020). Covid-19: India imposes lockdown for 21 days and cases rise. *British Medical Journal*, *368*, m1251. https://doi.org/10.1136/bmj.m1251

Qian, Y., Willeke, K., Grinshpun, S. A., Donnelly, J., & Coffey, C. C. (1998). Performance of N95 respirators: Filtration efficiency for airborne microbial and inert particles. *American Industrial Hygiene Association Journal*, *59*(2), 128–132. https://doi.org/10.1080/15428119891010389

Ramarao, B. V., Tien, C., & Mohan, S. (1994). Calculation of single fiber efficiencies for interception and impaction with superposed Brownian motion. *Journal of Aerosol Science*, *25*(2), 295–313. https://doi.org/10.1016/0021-8502(94)90081-7

Rengasamy, S., Eimer, B., & 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), 789–798. https://doi.org/10.1093/annhyg/meq044

Rengasamy, S., Eimer, B. C., & Szalajda, J. (2014). A quantitative assessment of the total inward leakage of NaCl aerosol representing submicron-size bioaerosol through N95 filtering facepiece respirators and surgical masks. *Journal of Occupational and Environmental Hygiene*, *11*(6), 388–396. https://doi.org/10.1080/15459624.2013.866715

Rheinbaben, F. V., Schünemann, S., Groß, T., & Wolff, M. H. (2000). Transmission of viruses via contact in ahousehold setting: experiments using bacteriophage φX174 as a model virus. *Journal of Hospital Infection*, *46*(1), 61–66. https://doi.org/10.1053/jhin.2000.0794

Rocklöv, J., & Sjödin, H. (2020). High population densities catalyze the spread of COVID-19. *Journal of Travel Medicine*, *27*(3), taaa038. https://doi.org/10.1093/jtm/taaa038

Rocklöv, J., Sjödin, H., & Wilder-Smith, A. (2020). COVID-19 outbreak on the Diamond Princess cruise ship: Estimating the epidemic potential and effectiveness of public health countermeasures. *Journal of Travel Medicine*, *27*(3), taaa030. https://doi.org/10.1093/jtm/taaa030

Roy, C. J., & Milton, D. K. (2004). Airborne transmission of communicable infection–The elusive pathway. *New England Journal of Medicine*, *350*(17), 1710–1712. https://doi.org/10.1056/NEJMp048051

Salah, B., Dinh Xuan, A. T., Fouilladieu, J. L., Lockhart, A., & Regnard, J. (1988). Nasal mucociliary transport in healthy subjects is slower when breathing dry air. *European Respiratory Journal*, *1*(9), 852.

Salath, M., Althaus, C. L., Neher, R., Stringhini, S., Hodcroft, E., Fellay, J., Zwahlen, M., Senti, G., Battegay, M., Wilder-Smith, A., Eckerle, I., Egger, M., & Low, N. (2020). COVID-19 epidemic in Switzerland: On the importance of testing, contact tracing and isolation. *Swiss Medical Weekly*, *150*, 11–12.

Santarpia, J. L., Rivera, D. N., Herrera, V., Morwitzer, M. J., Creager, H., Santarpia, G. W., & Lowe, J. J. (2020). Transmission potential of SARS-CoV-2 in viral shedding observed at the University of Nebraska Medical Center. *medRxiv*, 2020.2003.2023.20039446. https://doi.org/10.1101/2020.03.23.20039446

Schaffer, F. L., Soergel, M. E., & Straube, D. C. (1976). Survival of airborne influenza virus: Effects of propagating host, relative humidity, and composition of spray fluids. *Archives of Virology*, *51*(4), 263–273. https://doi.org/10.1007/bf01317930

Seah, I., & Agrawal, R. (2020). Can the coronavirus disease 2019 (COVID-19) affect the eyes? A review of coronaviruses and ocular implications in humans and animals. *Ocular Immunology and Inflammation*, *28*(3), 391–395. https://doi.org/10.1080/09273948.2020.1738501

Shakya, K. M., Noyes, A., Kallin, R., & Peltier, R. E. (2017). Evaluating the efficacy of cloth facemasks in reducing particulate matter exposure. *Journal of Exposure Science & Environmental Epidemiology*, *27*(3), 352–357. https://doi.org/10.1038/jes.2016.42

Shaman, J., & Kohn, M. (2009). Absolute humidity modulates influenza survival, transmission, and seasonality. *Proceedings of the National Academy of Sciences of the United States of America*, *106*(9), 3243. https://doi.org/10.1073/pnas.0806852106

Shaman, J., Pitzer, V. E., Viboud, C., Grenfell, B. T., & Lipsitch, M. (2010). Absolute humidity and the seasonal onset of influenza in the continental United States. *PLOS Biology*, *8*(2), e1000316. https://doi.org/10.1371/journal.pbio.1000316

Shechmeister, I. L. (1950). Studies on the experimental epidemiology of respiratory infections. III. Certain aspects of the behavior of type A influenza virus as an air-borne cloud. *Journal of Infectious Diseases*, *87*(2), 128–132. https://doi.org/10.1093/infdis/87.2.128

Sim, S. W., Moey, K. S. P., & Tan, N. C. (2014). The use of facemasks to prevent respiratory infection: A literature review in the context of the Health Belief Model. *Singapore Medical Journal*, *55*(3), 160–167. https://doi.org/10.11622/smedj.2014037

Singh, J., & Datta, K. K. (1997). Epidemiological considerations of the age distribution of measles in India: A review. *Journal of Tropical Pediatrics*, *43*(2), 111–115. https://doi.org/10.1093/tropej/43.2.111

Singhal, T. (2020). A review of coronavirus disease-2019 (COVID-19). *Indian Journal of Pediatrics*, *87*(4), 281–286. https://doi.org/10.1007/s12098-020-03263-6

Sloan, C., Moore, M. L., & Hartert, T. (2011). Impact of pollution, climate, and sociodemographic factors on spatiotemporal dynamics of seasonal respiratory viruses. *Clinical and Translational Science*, *4*(1), 48–54. https://doi.org/10.1111/j.1752-8062.2010.00257.x

Stanley, W. M. (1944). The size of influenza virus. *Journal of Experimental Medicine*, *79*(3), 267–283. https://doi.org/10.1084/jem.79.3.267

Strzelecki, A. (2020). The second worldwide wave of interest in coronavirus since the COVID-19 outbreaks in South Korea, Italy and Iran: A Google Trends study. *Brain, Behavior, and Immunity*, *88*, 950–951. https://doi.org/10.1016/j.bbi.2020.04.042

Stutt, R. O. J. H., Retkute, R., Bradley, M., Gilligan, C. A., & Colvin, J. (2020). A modelling framework to assess the likely effectiveness of facemasks in combination with 'lock-down' in managing the COVID-19 pandemic. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *476*(2238), 20200376. https://doi.org/10.1098/rspa.2020.0376

Syed, Q., Sopwith, W., Regan, M., & Bellis, M. A. (2003). Behind the mask. Journey through an epidemic: Some observations of contrasting public health responses to SARS. *Journal of Epidemiology and Community Health*, *57*(11), 855–856. https://doi.org/10.1136/jech.57.11.855

Tamerius, J., Nelson, M. I., Zhou, S. Z., Viboud, C., Miller, M. A., & Alonso, W. J. (2011). Global influenza seasonality: Reconciling patterns across temperate and tropical regions. *Environmental Health Perspectives*, *119*(4), 439–445. https://doi.org/10.1289/ehp.1002383

Tarwater, P. M., & Martin, C. F. (2001). Effects of population density on the spread of disease. *Complexity*, *6*(6), 29–36. https://doi.org/10.1002/cplx.10003

Tatem, A. J., Rogers, D. J., & Hay, S. I. (2006). Global transport networks and infectious disease spread. In S. I. Hay, A. Graham, & D. J. Rogers (Eds.), *Advances in parasitology* (Vol. *62*, pp. 293–343). Academic Press.

Tellier, R. (2006). Review of aerosol transmission of influenza A virus. *Emerging Infectious Diseases*, *12*(11), 1657–1662. https://doi.org/10.3201/eid1211.060426

Tong, T., & Lai, T.-S.-T. (2005). The severe acute respiratory syndrome coronavirus in tears. *British Journal of Ophthalmology*, *89*(3), 392. https://doi.org/10.1136/bjo.2004.054130

van Doremalen, N., Bushmaker, T., Morris, D. H., Holbrook, M. G., Gamble, A., Williamson, B. N., Tamin, A., Harcourt, J. L., Thornburg, N. J., Gerber, S. I., Lloyd-Smith, J. O., de Wit, E., & Munster, V. J. (2020). Aerosol and surface stability of SARS-CoV-2 as Compared with SARS-CoV-1. *New England Journal of Medicine*, *382*(16), 1564–1567.https://doi.org/10.1056/NEJMc2004973

Viboud, C., Miller, M. A., Grenfell, B. T., Bjørnstad, O. N., & Simonsen, L. (2006). Air travel and the spread of influenza: Important caveats. *PLoS Medicine*, *3*(11), e503. https://doi.org/10.1371/journal.pmed.0030503

Wang, C.-S. (2001). Electrostatic forces in fibrous filters—a review. *Powder Technology*, *118*(1), 166–170. https://doi.org/10.1016/S0032-5910(01)00307-2

Wang, X., Ferro, E. G., Zhou, G., Hashimoto, D., & Bhatt, D. L. (2020). Association Between Universal Masking in a Health Care System and SARS-CoV-2 Positivity Among Health Care Workers. *JAMA*, *324*(7), 703-704. https://doi.org/10.1001/jama.2020.12897

Wanka, E. R., Bayerstadler, A., Heumann, C., Nowak, D., Jörres, R. A., & Fischer, R. (2014). Weather and air pollutants have an impact on patients with respiratory diseases and breathing difficulties in Munich, Germany. *International Journal of Biometeorology*, *58*(2), 249–262. https://doi.org/10.1007/s00484-013-0730-3

Warachit, B., Hutagalung, Y., Lolekha, S., Weil, J., Sornchai, P., Tanthiphabha, W., Sutra, S., Chup-Upprakarn, S., Bock, H. L., & Kosuwan, P. (2001). Effect of climatic factors and population density on varicella zoster virus epidemiology within a tropical country. *American Journal of Tropical Medicine and Hygiene*, *64*(3), 131–136. https://doi.org/10.4269/ajtmh.2001.64.131

Welliver, R. (2009). The relationship of meteorological conditions to the epidemic activity of respiratory syncytial virus. *Paediatric Respiratory Reviews*, *10*(Suppl 1), 6–8. https://doi.org/10.1016/s1526-0542(09)70004-1

WHO (1999). *Hazard prevention and control in the work environment: Airborne dust*. Retrieved from Geneva https://apps.who.int/iris/handle/10665/66147

WHO (2020a). *Coronavirus disease (COVID-19) advice for the public: When and how to use masks*. Retrieved from https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public/when-and-how-to-use-masks

Willem, L., Van Kerckhove, K., Chao, D. L., Hens, N., & Beutels, P. (2012). A nice day for an infection? Weather conditions and social contact patterns relevant to influenza transmission. *PLoS One*, *7*(11), e48695. https://doi.org/10.1371/journal.pone.0048695

WHO (2020b). *Coronavirus disease (COVID-19) advice for the public: When and how to use masks*. Retrieved from https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public/when-and-how-to-use-masks

Wu, H.-L., Huang, J., Zhang, C. J. P., He, Z., & Ming, W.-K. (2020). Facemask shortage and the novel coronavirus disease (COVID-19) outbreak: Reflections on public health measures. *EClinicalMedicine*, *21*, 100329. https://doi.org/10.1016/j.eclinm.2020.100329

Yi, L., Fengzhi, L., & Qingyong, Z. (2005). Numerical simulation of virus diffusion in facemask during breathing cycles. *International Journal of Heat and Mass Transfer*, *48*(19), 4229–4242. https://doi.org/10.1016/j.ijheatmasstransfer.2005.03.030

Yunus, A. S., Jackson, T. P., Crisafi, K., Burimski, I., Kilgore, N. R., Zoumplis, D., Allaway, G. P., Wild, C. T., & Salzwedel, K. (2010). Elevated temperature triggers human respiratory syncytial virus F protein six-helix bundle formation. *Virology*, *396*(2), 226–237. https://doi.org/10.1016/j.virol.2009.10.040

Zeytuncu, B., Ürper, M., Koyuncu, İ., & Tarabara, V. V. (2018). Photo-crosslinked PVA/PEI electrospun nanofiber membranes: Preparation and preliminary evaluation in virus clearance tests. *Separation and Purification Technology*, *197*, 432–438. https://doi.org/10.1016/j.seppur.2018.01.002

Zhang, S., Rind, N. A., Tang, N., Liu, H., Yin, X., Yu, J., & Ding, B. (2019). Chapter 12 – Electrospun nanofibers for air filtration. In B. Ding, X. Wang, & J. Yu (Eds.), *Electrospinning: Nanofabrication and applications* (pp. 365–389). William Andrew Publishing.

Zhang, W., Du, R.-H., Li, B., Zheng, X.-S., Yang, X.-L., Hu, B., Wang, Y.-Y., Xiao, G.-F., Yan, B., Shi, Z.-L., & Zhou, P. (2020). Molecular and serological investigation of 2019-nCoV infected patients: implication of multiple shedding routes. *Emerging Microbes & Infections*, *9*(1), 386–389. https://doi.org/10.1080/22221751.2020.1729071

Zhen-Dong, G., Zhong-Yi, W., Shou-Feng, Z., Xiao, L., Lin, L., Chao, L., & Wei, C. (2020). Aerosol and surface distribution of severe acute respiratory syndrome coronavirus 2 in hospital wards, Wuhan, China, 2020. *Emerging Infectious Disease Journal*, *26*(7), 1583–1591. https://doi.org/10.3201/eid2607.200885

How to cite this article: Ahmed J, Harker A, Edirisinghe M. COVID-19: Facemasks, healthcare policies and risk factors in the crucial initial months of a global pandemic. *Med. Devices Sens.* 2020;3:e10120. https://doi.org/10.1002/mds3.10120