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Mask use during COVID-19: A risk adjusted strategy[☆]

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ABSTRACT

In the context of Coronavirus Disease (2019) (COVID-19) cases globally, there is a lack of consensus across cultures on whether wearing face masks is an effective physical intervention against disease transmission. This study 1) illustrates transmission routes of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2); 2) addresses controversies surrounding the mask from perspectives of attitude, effectiveness, and necessity of wearing the mask with evidence that the use of mask would effectively interrupt the transmission of infectious diseases in both hospital settings and community settings; and 3) provides suggestion that the public should wear the mask during COVID-19 pandemic according to local context. To achieve this goal, government should establish a risk adjusted strategy of mask use to scientifically publicize the use of masks, guarantee sufficient supply of masks, and cooperate for reducing health resources inequities.

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With the increasing number of Coronavirus Disease (2019) (COVID-19) cases globally, countries have utilized precautionary measures against this pandemic. However, there is a lack of consensus across cultures on whether wearing face masks is an effective physical intervention against disease transmission. This study aims to illustrate transmission routes of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), address the controversies surrounding mask wearing, and provides suggestions for the use of facial masks during the COVID-19 pandemic.

The references search was conducted on March 11, using three databases (PubMed, CNKI, and Web of Science) with the search terms “COVID-19”, “2019-nCoV”, “novel coronavirus”, or “SARS-CoV-2” and “mask”, “facial mask”, or “face mask”. The team members individually assessed the relevance and validity of each study. Non-peer reviewed manuscripts from preprint servers were not considered. We also searched the reference lists of the studies included. Findings from the included studies were summarized narratively.

1. Transmission routes and characteristics of SARS-CoV-2

1.1. Transmission routes of SARS-CoV-2

Main transmission routes of SARS-CoV-2 include droplet and contact transmissions, airborne transmission may be possible in specific circumstances and settings in which aerosol generating procedures (AGP) are performed (World Health Organization, 2020c). Although the virus nucleic acid could be detected in fecal specimens, there has been no public reports on fecal-oral transmission yet (Xie et al., 2020; Zhang et al., 2020a). Since the droplet could enter susceptible mucosal surface within a certain distance (usually less than 1 m), daily face-to-face talk, breathing, cough and sneezing may result in droplet transmission from respiratory tract. The droplet can further form aerosols, which are able spread to a wider range (>1 m) with the air currents and survive for a longer time in the environment. For example, a confirmed case took a bus for 2 h led to the infections of 7 people, and there was no direct contact among them, implying the possibility of aerosol transmission (Luo et al., 2020). It has been found that SARS-CoV-2 could remain viable in aerosols for 3 h and is more stable on plastic (72 h), stainless steel (48 h), copper (4 h), and cardboard (24 h) surfaces (van Doremalen et al., 2020). With the presence of symptomatic patients, their surrounding surfaces (e.g. air outlet fans, toilet bowl,

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sink, door handle, etc.) could be contaminated (Ong et al., 2020). This was confirmed by the finding that SARS-CoV-2 nucleic acid was detected in environmental samples in Huanan Seafood Market in Wuhan, China (Xinhua Net, 2020). Similarly, SARS-CoV-2 RNA was identified on a variety of surfaces in cabins of both symptomatic and asymptomatic infected cases up to 17 days after cabins were vacated on the Diamond Princess cruise ship (Moriarty et al., 2020). The aerosol deposition on the surface and subsequent resuspension could also be a potential transmission route. In an SARS-CoV-2 aerosol study in Wuhan, China, high viral RNA concentration was observed inside the patient mobile toilet room (19 copies m^{-3}) and medical staff areas (11–42 copies m^{-3}) in Make-shift Hospital; in particular, the viral RNA concentration in protective apparel removal rooms was high (18–42 copies m^{-3}) until the number of medical staff reduced or more rigorous sanitization processes were implemented (Liu et al., 2020). Also, transmission of SARS-CoV-2 via air conditioning system is plausible. In a study of reproductive number estimation of COVID-19 on the Diamond Princess cruise ship, Zhang et al. pointed out that aerosol transmission via the central air conditioning system might be neglected because of high R_0 under the quarantine measures (Zhang et al., 2020b). An earlier study also revealed the possibility of coronavirus spread via air conditioner. Du et al. examined SARS-CoV in samples using routine Reverse Transcription PCR (RT-PCR) and found that all dust samples and half of condensation water samples from the air conditioners were positive (Du et al., 2005).

1.2. High proportion of cases with mild symptom or asymptomatic cases

Another important feature of the COVID-19 is that asymptomatic cases proportion is high. It is estimated approximately 60% of all infections convert from cases with mild symptom or asymptomatic cases and might be passing the virus on to others (Qiu, 2020). Of the confirmed cases in Diamond Princess cruise ship, approximately 17.9% of infected people never developed symptoms, leading to high attack rate among cruise ship passengers and crew (Mizumoto et al., 2020). This proportion echoes with the finding of an epidemiological characteristics of COVID-19 close contacts in Ningbo, China that 16.7% of infected cases were asymptomatic (Chen et al., 2020). The proportion of asymptomatic cases was estimated to be 16.38% and 27.56% in Hubei and other provinces in China, respectively (data from China CDC). The transmission rate of undocumented infections, those who undergo mild, limited, or no symptoms and hence go unrecognized, was 55% of documented infections (46%–62%) due to high quantity, and undocumented infections were the infection source of 79% of documented cases (Li et al., 2020), leading to a great public health threat.

1.3. Strong infectivity of SARS-CoV-2

The basic reproductive number (R_0) of the SARS-CoV-2 is estimated to range from 1.4 to 3.9 (van Doremalen et al., 2020; Wu et al., 2020a). The infectivity is greater than that of seasonal influenza (0.9–2.1) and MERS (0.29–1.44), which is close to SARS (~3) (Coburn et al., 2009; World Health Organization, 2003; Yin and Wunderink, 2018). However, global spread of SARS-CoV-2 is far greater than MERS and SARS, which might be associated with cases with mild symptom or asymptomatic cases. According to Wrapp et al. the binding of SARS-CoV-2 to the obligate receptor of Angiotensin Converting Enzyme 2 (ACE2) is of higher affinity than that of SARS-CoV (Wrapp et al., 2020), indicating that those with medical comorbidities may be at higher risks. This may also indicate a higher time to infection, even in the absence of masks (Pung et al., 2020). For example, there has been case reports of infection

that took only 15 s standing in front of a stall in the vegetable market together with a confirmed case without wearing masks (Jiangbei News, 2020). Making matters worse, cases in the incubation period might also have a certain degree of infectivity (Rothe et al., 2020). For example, a case visited Germany from China, participated in a business conference, but the symptoms did not appear until that case travelled back to China. Three days later, the patient was positive in COVID-19 test. Two days later, his associates displayed symptoms and were subsequently confirmed.

1.4. Cluster epidemics of COVID-19

Due to strong infectivity and high proportion of asymptomatic cases, the cluster COVID-19 transmission becomes a difficult containment issue. In some regions, the number of cases related to the cluster transmission can reach 50%–80% of the total cases (Gopinath, 2020). At present, cluster cases of COVID-19 have been reported in relatively confined or congregated places such as shopping malls, offices, buses, cruises, prisons, hospitals, and nursing homes. Ong et al. found that the detection results of samples collected at the hospital air outlet were positive, suggesting that the SARS-CoV-2 could pollute the environment through the droplet of patients (Ong et al., 2020). Wu et al. investigated the cluster epidemic situation of a department store and found that the close distance between the salesman and the customer was easy to cause respiratory transmission when talking (Wu et al., 2020b). It is also reported that several senior officials in some countries were diagnosed as COVID-19 cases, which might be related to participation of public gatherings such as parliamentary meetings, receptions and commemorative activities without wearing masks. Cases who come into contact with a large number of individuals through work or socially may become “super-spreaders” if they do not exercise preventive measures.

2. Perceptions of the mask

By June 10, 2020, SARS-CoV-2 has led to more than 7.1 million confirmed cases and over 0.4 million deaths (World Health Organization, 2020b). Despite the consistency in the recommendation that symptomatic individuals and those in healthcare settings should use face masks, discrepancies were observed in the general public and community settings (Feng et al., 2020). These discrepancies could be analyzed from perspectives of attitude, effectiveness, and necessity.

2.1. The attitude towards the mask in different countries

In the past two decades, countries in East Asia have experienced infectious disease epidemics or air pollution episodes, such as Severe Acute Respiratory Syndrome (SARS), avian influenza, influenza, and haze events. Hence, wearing masks has become a pervasive in society as a way to prevent exposure. This is for good reason, as the population density in Asian countries is generally higher than that in western countries, and the crowding in a confined place will increase the infection risk or exposure. Therefore, during the COVID-19 pandemic, the public is encouraged to wear masks in public places and people often comply as a form of health-seeking behavior (Greenhalgh et al., 2020).

However, in many western advanced economies, those wearing masks are often met with suspicion in public, even causing panic in certain situation. Universal mask use in the community has been discouraged by some health authorities with the argument that masks provide no effective protection against coronavirus infection (Feng et al., 2020). Although the 1918 Pandemic (H1N1 virus) caused an estimated 40–50 million deaths worldwide, many still

may view personal protective equipment (PPE) and physical barrier including wearing the mask as contrary to freedom and individualism (World Health Organization, 2005). Furthermore, there are some cultural underpinning of the use of masks as well, as it was partially prohibited by the introduction of no mask act under the background of increasing political demonstration and terrorist attacks. Since the transmission route of SARS-CoV-2 has not been fully understood, thus wearing masks should indeed be a cautionary prevention course of action.

So far, regulatory agencies and health care providers in all parts of the world have agreed on the mask use in hospital and laboratory settings, the present controversy over wearing masks is mostly focused on the effectiveness of the mask and the necessity of wearing masks in the community setting. The difference in conclusions of mask effectiveness studies is mainly due to different study contents, study designs, evaluation methods and endpoints. Understandably, good evidence on this topic is difficult to assess. Many studies used self-reported questionnaire to quantify mask uptake status, which may introduce subjective bias because the description depends on perception of participants (Barasheed et al., 2016). In addition, when the proportion of people who wear masks is too low in a group, the impact of wearing masks on disease transmission would be limited (Elachola et al., 2014).

2.2. The effectiveness of the mask

As a basic non-pharmaceutical intervention (NPI) measure, wearing a mask is an effective means of preventing respiratory infectious diseases, which could reduce the risk of infection (World Health Organization Writing Group, 2006). In this study, mask is defined as a device covering the mouth and nose providing a barrier to minimize the direct transmission of infective agents according to relevant standards, including disposable medical mask, surgical mask, and respirator with or without valve, etc. (British Standards Institution, 2019; Standardization administration of China, 2016). In a large systematic review of physical interventions to control spread of infectious diseases, Jefferson et al. concluded from 67 studies that wearing masks is effective as one of the important barriers to transmission of respiratory viruses, and evidences indicate N95 respirators were non-inferior to surgical masks (Jefferson et al., 2011). Other studies also found evidence that wearing masks can significantly reduce the risk of SARS and influenza-related diseases (Jefferson et al., 2009; Macintyre et al., 2009; Zhang et al., 2013). Aldila et al. constructed MERS determinant mathematical model and found that compared with auxiliary nursing and government publicity, wearing masks is the optimal choice for reducing the number of infections (Aldila et al., 2018). In addition, the costs of wearing masks is also the lowest for society, as it is a simple low-cost intervention (Aldila et al., 2018). During SARS epidemic, a survey conducted in the United States, Singapore, Chinese Taiwan, and Hong Kong showed that the meaning of wearing masks has exceeded their direct effects in disease prevention and has become a means of raising public awareness of other NPIs, such as isolation (Pillemer et al., 2015). Barasheed et al. systematically analyzed the utilization and effectiveness of masks by integrating 12,710 samples from more than 50 countries in the world, and found that wearing masks in crowded places could reduce the risk of respiratory infections by 20% (Barasheed et al., 2016). A study in Hong Kong found that the odds ratio (OR) value of wearing masks in public places was only 0.36, which was lower than that of living room disinfection (OR = 0.41) and frequent hand washing (OR = 0.58), indicating that wearing masks effectively restricted the community spread of SARS-CoV in Hong Kong (Lau et al., 2004).

2.3. The necessity of wearing the mask

The necessity of wearing masks by the public during COVID-19 pandemic is under-emphasized in some countries. It was implied that the public could be well protected via hand hygiene in the absence of masks (CDC, 2020a). While effectiveness of hand hygiene against virus infection and transmission, such as influenza, is difficult to be determined in the community setting because of limited studies and heterogeneous study designs (Moncion et al., 2019). Wong et al. reviewed 10 randomized controlled trails and concluded that the hand hygiene along did not have statistically significant efficacy against laboratory-confirmed influenza (Wong et al., 2014). Considering the effect of masks, Aiello et al. carried out a randomized intervention trial in university residence halls during the influenza season, they observed a 35%–51% reduction in influenza-like illness (ILI) in the mask and hand hygiene group compared with the no mask group during 2006–2007 (Aiello et al., 2010). Therefore, they emphasized that mask and hand hygiene should be encouraged during seasonal influenza outbreaks, especially during the beginning of a pandemic when vaccines may not be available. The effectiveness of community use of masks was found to be related with the reduction of the clinical infection risk by preventing from pathogens inhalation and reducing hand-to-face contact (Macintyre et al., 2009). Moreover, Macintyre and Chughtai found that masks and masks plus hand hygiene may prevent infection in community settings (MacIntyre and Chughtai, 2015). Taken together, these evidences implied that wearing masks would be able to reduce the burden of infectious diseases.

3. A risk adjusted strategy for mask use during COVID-19 pandemic

Considering the transmission route and characteristics of SARS-CoV-2, wearing masks is an indispensable measure to prevent droplet and possible aerosol transmission, as well as reduce the hand-to-face contact, especially under the prerequisite of infectivity of asymptomatic cases, as well as in the relatively confined or congregated places. Although most countries and regions have established guidelines of PPE use to cope with the pandemic, there is still some discrepancies from the perspective of masks. In the United States, a cloth face is required by Centers for Disease Control and Prevention (CDC) for people over age 2 when going out in public, and use of facemask meant for a healthcare worker has been advised against (CDC, 2020b). While in Singapore, the use of masks is mandatory when people go outside their homes and face shield is advised for children under age 12, people with breathing or other medical difficulties when wearing the mask for a prolonged period of time, and people speaking to a group in classroom or lecture-style settings (Ministry of Health, 2020). WHO claims that masks are effectively only when used in combination with hand hygiene and knowledge of proper use and disposal; in addition, mask use is needed for healthcare workers, general population in public settings, transportation, people living in cramped conditions, vulnerable populations, as well as people with any symptoms suggestive of COVID-19 (World Health Organization, 2020a). Unlike SARS-CoV-1 and MERS-CoV, the SARS-CoV-2 is likely to infect people during incubation, and asymptomatic patients also have potential infectivity. Suppose if only symptomatic cases wore masks, we would miss those asymptomatic cases, which increases the possibility of spreading the virus before realization that they carry the virus. However, we should note that requiring the general public to wear masks would put high pressure on mask supply, and insufficient guidance would even trigger a run on medical protection products creating a lack of PPE for medical professionals. Therefore, scientific strategy and strategic guidance should be established, and enough

Table 1
The mask use strategy in different scenarios based on risks (Bureau of Disease Control and Prevention, 2020).

Population	Scenario	Risk	Mask
General public	Residential and outdoor environments or places with adequate ventilation and no gatherings	–	No mask
	Crowded places such as offices, shopping malls, restaurants, conference room, etc. or relatively closed environments such as elevators, transportation vehicles, etc.	High ^a Middle ^b to low ^c	Disposable medical mask Disposable medical mask (when distance between surrounding people is within 1 m)
People in specific places	People who has symptoms of cough or sneezing	–	Disposable medical mask or surgical mask
	People who lives together with recovered COVID-19 patients or isolated individuals	–	Disposable medical mask or surgical mask
	Public crowded places such as hospitals, railway stations, airport, supermarkets, restaurants, etc.	High Middle to low	Surgical mask or respirator Disposable medical mask or surgical mask
Key people	Relatively closed crowded places such as prison, nursing homes, classrooms, dormitories, etc.	High Middle to low	Workers: surgical mask or respirator Others: disposable medical mask Disposable medical mask or surgical mask (when people gather or distance between surrounding people is within 1 m)
	Suspected cases, confirmed cases, asymptomatic carriers, and close contacts	–	Surgical mask or respirator without valve
	Occupational exposed worker	High to middle Low	Medical respirator Surgical mask
	Healthcare workers in general outpatient clinics or wards, administrative personnel such as police, security, cleaning workers, etc.	–	Surgical mask
	Workers in ICU or wards of confirmed cases or suspected cases; healthcare workers of the fever clinic in designated hospitals; laboratory detection personnel; epidemiological investigation personnel; environmental disinfection personnel; environmental infection worker; personnel who transport confirmed or suspected cases	–	Medical respirator

^a High risk denotes to cumulative confirmed cases over 50 with clusters in 14 d in the region.
^b Medium risk denotes to cumulative confirmed cases of 1–50 or cumulative confirmed cases over 50 without clusters in 14 d in the region.
^c Low risk denotes to cumulative confirmed cases over 50 with clusters in 14 d in the region.

mask supply should be guaranteed under the frame of inter- or intra-national cooperation.

3.1. To establish mask use strategies for different population and scenarios

As Tedros Adhanom Ghebreyesus, the WHO Director-General, mentioned on March 18, 2020, “do not assume you will not be infected, prepare as if you will die” (Ghebreyesus, 2020). The Government of China has implemented a risk-based mask use strategy for general public, people in public congregated places and confined congregated places, confirmed/suspected cases and close contacts, and occupational exposed workers under various scenarios, which could be used as a reference (Table 1). As an example, during the COVID-19 pandemic, it is suggested to wear the mask in congregated places such as offices, shopping malls, restaurants, conference room, etc. or relatively confined environments such as elevators, transportation vehicles, etc. The mask is generally used by general public, while the respirator or a filtering face piece, which is designed to protect the wearer from exposure to airborne contaminants, is mainly used by health care workers especially during AGP (European Centre for Disease Prevention and Control, 2020). The exhalation valve is sometime used in the respirator in order to reduce the breathing resistance. However, the inhalation valve closes and the exhalation valve opens of the mask when the wearer breathing, implying that the exhaled gas is not filtered and directly discharged into the surrounding environment. As a result, the respirator recommended for suspected cases, confirmed cases, asymptomatic carriers, and close contacts must not contain the valve (CDC, 2020c). Moreover, considering the probable insufficient mask production, masks could be repeatedly used under the prerequisite of public health protection in areas with middle to low risks.

3.2. To scientifically publicize the use of masks

Rational guidance should be provided concerning the use of masks. The content of messages to the public should include 1) the necessity of wearing the mask; 2) selection of the proper masks; 3) rational use of the mask in different situations; 4) disposable of the mask; and 5) other prevention and control measures which should not be neglected. There is not a single measure that could provide complete protection to the public. Therefore, mask use must be combined with hand hygiene, ventilation improvement, reduction of gatherings, and social and physical distancing. To inform the public, the government could 1) invite mainstream press such as TV stations, broadcasts, newspapers, etc. to participate in mask education; 2) spread relevant knowledge via social media (e.g. Twitter, Facebook, and Instagram) or display screens and billboards in public places; 3) hand out mask instruction materials to the public; and 4) carry out training and seminars in places such as hospitals, schools, kindergartens.

3.3. To guarantee sufficient supply of masks

As the use of masks during the COVID-19 pandemic would contribute to the rapid consumption of masks in limited time, two essential countermeasures should be taken into consideration. The government should timely stimulate mask production. Many countries have been facing a severe shortage of medical resources, including medical masks. In this circumstance, the mask price increased sharply, and the public stole or fought for masks in some regions; in addition, diplomatic disputes even arose. To solve this problem, the government could 1) procure surgical masks globally through different channels and means; 2) distribute masks in accordance with risk level; and 3) explore prospects of local production. Research on mask reuse should also be encouraged. For example, Song et al. has proposed an approach for medical mask

use using hairdryer, and they are still working on further improvement (Song et al., 2020). After the treatment, the medical mask could be used by the public, but the reuse in a hospital settings is still unexplored.

3.4. To cooperate for reducing health resources inequities

The face mask distribution priority should be given to healthcare workers providing care services (e.g. front-line healthcare workers, nursing staff in institutions, and healthcare personnel in private clinics); personnel who provide essential services and who are required to have contact with the public at work (e.g. those providing public transport, emergency services and immigration services); and vulnerable groups in the society (e.g. unaccompanied children, elderly people without family support, and disabled persons).

The globe is more interconnected than ever; if the countries with weaker health systems fail to control the pandemic, other countries would be re-exposed by the COVID-19 for the foreseeable future. If the countries with weak health systems fail to control the pandemic, other countries would be exposed in the danger of being harassed by the COVID-19 for the long term. As chief of U.N. claimed, "We must create the conditions and mobilize the resources necessary to ensure that developing countries have equal opportunities to respond to this crisis in their communities and economies" (United Nations Secretary-General, 2020). In mid-February, France took early action to help China, sending 17 tons of similar supplies. Under the well control of COVID-19, China has sent supplies to Italy, the hardest hit among European countries, and to Spain (US News, 2020a). Case in point, LVMH, the world's biggest luxury goods group, has also ordered 40 million health masks from a Chinese supplier to help France coping with this pandemic (US News, 2020b). It could be seen that international cooperation, with manufacturing and distribution logistics may optimize mask resource allocation.

In each country, the most vulnerable group should be paid more attention when distributing masks. They have lower health levels, weaker affordability of medical costs, and a higher proportion of infection. The neglect of this group would increase the possibility of the long-term presence of COVID-19 in society, causing continuous economic losses. Therefore, the government should establish a strategy in distribution method of masks to protect the benefits of the vulnerable group and eliminate the health inequities due to mask shortage. For example, enclosed institutional facilities such as nursing homes and orphanages are places with great potential for cluster outbreak of COVID-19. Furthermore, the elderly and children are susceptible to respiratory infectious diseases. Lastly, government may keep a certain number of masks in reserve to satisfy the urgent need for this population. For now, people around the world should not miss the opportunity to wear face masks to mitigate spread of SARS-CoV-2.

4. Conclusion

In the context of rapid spread of COVID-19 globally, there is a lack of consensus on the mask use as a NPI amidst the pandemic. This study summarized that: 1) main transmission routes of SARS-CoV-2 include droplet, contact transmissions, and possible airborne transmissions, which is characterized by high proportion of cases with mild symptom or asymptomatic cases, strong infectivity, and a large number of clusters; 2) The necessity of wearing masks by the public during COVID-19 pandemic has been under-emphasized; and 3) A risk basis mask use strategies and compliance improvement are suggested.

Contributors

JW and XS had the idea for and designed the study. JW and LP drafted the paper, and all authors critically revised the manuscript for important content and gave final approval for the version to be published. All authors agree to be accountable for all aspects of the work in ensuring that questions related to any part of the work are appropriately investigated and resolved. JW and LP contributed equally to this work.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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