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Public face masks wearing during the COVID-19 pandemic: A comprehensive analysis is needed for potential implications

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ABSTRACT

Face mask-wearing as a public health measure has been practiced since the coronavirus 2019 (COVID-19) pandemic outbreak. Extensive research has shown that face masks are an effective non-pharmaceutical measure to contain the spread of respiratory infections. However, recent studies indicate that face masks release microplastics and other contaminants that have adverse health effects on humans. This communication reviews the evidence for face mask as a potential source of contaminants capable of adversely affecting human health. The benefits of face masks in reducing the transmission of SARS-Cov-2 (severe acute respiratory syndrome coronavirus 2) and seasonal communicable diseases were addressed. In addition, the risk of inhaling microplastics and organic contaminants, as well as the associated exposure level, were discussed. Finally, the potential research gaps that need to be addressed were outlined to provide a holistic view of the problem. This communication has illustrated that face mask-wearing as a public health measure to contain the spread of COVID-19 could be a potential risk factor for human health. Very few studies have been done on microplastics, organic pollutants, and trace metal inhalation from surgical masks. However, future work providing a comprehensive understanding of the risk and exposure levels needs to be undertaken.

1. Introduction

Public face mask wearing has been the norm across the globe since the outbreak of the coronavirus 2019 (COVID-19) pandemic. Numerous studies have confirmed the effectiveness of medical and non-medical masks as a nonpharmaceutical measure in reducing the prevalence of COVID-19 in community settings (Cheng et al., 2020; Eikenberry et al., 2020; Howard et al., 2021). The most commonly used face masks are surgical, N95, and cloth masks, with surgical masks being the most prevalent. While disputes still persist on the effectiveness of the different types of masks (e.g., N95 respirators, surgical masks, homemade cloth masks) (Feng et al., 2020; Loeb et al., 2009), the proper wearing of masks irrespective of the kind, difference in design and effectiveness, ~~stems~~ curbs the overall risks of contracting COVID-19 infections (Wang et al., 2021). Furthermore, greater benefits of public mask wearing are reaped when compliance is high (Howard et al., 2021). Globally, over 90 percent of countries had laws in place requiring some form of mask use in public settings (Masks for All, 2021). While global mask usage has been a common feature since the onset of the pandemic, it is unclear when this is going to cease being the case given that 48 countries are not on track to meet WHO's target of inoculating 70% of their population by the end of June 2022, and the African continent will not reach the same goal by August 2024 (Ravelo and Jerving, 2021). The likelihood of protracted mask use further lingers in light of the fact that halting the emergence of variants is contingent on limiting transmissions by wearing masks and vaccinating as many people as possible to achieve herd immunity (Page, 2021). In the race to eliminate the COVID-19 pandemic, it is imperative to gain more insight into the pros and cons of long-term mask usage.

The environmental dangers associated with poorly disposed ~~of~~ face masks such as a surge in plastic waste pollution, bioaccumulation of microplastics in the food web, animal entanglement and death, have been highlighted in numerous reports (Benson et al., 2021; Boyle, 2020; Patrício Silva et al., 2021, 2020; Selvaranjan et al., 2021). A recent review by Tesfaldet and Ndeh (2022) hinted at the physiological and psychological implications of prolonged mask usage in the form of decreased work efficiency, headaches, acne, impaired cognition, and difficulties breathing on exertion. The occurrence of headaches is linked to the increased carbon dioxide concentration in the inhaled air during mask wearing (Huo and Zhang, 2021). Increase carbon dioxide concentration in the inhaled air might be attributed to the contribution of air trapped in the dead space between the mask and the face containing higher carbon dioxide than freely expired air. As far as the dangers related to the upsurge in global mask usage goes, the spotlight has been focused largely on environmental implications. While there have been a number of reports on the release of nanoplastics and microplastics from

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surgical (Liang et al., 2022; Ma et al., 2021), even fewer reports have investigated the risk of their inhalation (Li et al., 2021). In the same vein, a critical review done by Kutralam-Muniasamy et al. (2022) indicated that a single mask can release up to 6.0×10^9 microplastics. The potential risk of inhalation stems not only from the mask material but also from microplastics in the air emanating from other sources. The possibility of this happening is not improbable given that previous investigators have described the presence of mineral (e.g., asbestos) and non-mineral (e.g., plant and plastic) fibers in lung tissues (Pauly et al., 1998). More recently, Chen et al. (2022) detected the presence of microfibers in the lungs. The authors attributed the origin of these pulmonary microfibers from indoor or outdoor air sources. Another study by Yao et al. (2022) conducted in New Jersey went as far as exploring the characteristics of microplastics in indoor and ambient air in the region. The researchers noted that the main microplastic constituents in indoor and ambient air samples were PE (polyethylene) particles or fibers and PVC (polyvinyl chloride) fragments, respectively.

Broadly speaking, associated contaminants like polycyclic aromatic hydrocarbons (PAHs) and phthalates, also known to have been identified in face masks (Jin et al., 2021), could potentially desorb to elicit other health complications, including reproductive toxicity and mutagenicity (Gasperi et al., 2018). More specifically, several studies on different face mask brands have reported the association and release of a wide range of additives such as endocrine disrupting UV stabilizers, nanofiber-infused engineered nanoparticles, heavy metals (e.g., Pb, Cd, Sb and Cu) and dyes (Ardusso et al., 2021; Fukuoka et al., 2022; Sullivan et al., 2021). Gasperi et al. (2018) further acknowledged that plastic microfibers are not strictly confined to outdoor environments but could also be found in indoor surroundings. Considering the tendency for people to remain unmasked while indoors at home, coupled with increased levels of indoor pollution during the heart of the lockdown, meant that the risk of exposure to a host of pollutants was amplified. Having a mask on mitigates some of the risks linked to both indoor and outdoor air pollutants, though the protection offered to wearers varies across the board for different mask types. Furthermore, the duration of mask use and reuse following subjection to different disinfection processes has a bearing on the risk of exposure to spherical- and fiber-like microplastics inhalation (Li et al., 2021). To illustrate, fiber-like microplastic risk of inhalation from untreated masks, except for N95, increased over time for a duration of 720 h when compared with the absence of mask. In the same breath, risk of spherical-type microplastic inhalation continuously decreased. Although there are articles that provide risks associated with PPE use, the benefits are not addressed (De-la-Torre et al., 2021). Therefore, it is important to evaluate both the risks and benefits to come up with clear research directions. In this short communication we attempt to show the benefits and dangers associated with face mask wearing. Moreover, the knowledge gaps are highlighted to provide pathways for comprehensive research. The specific objective of this study is to emphasize the need for further research on the risk and benefits associated with the public wearing surgical face masks during the COVID-19 pandemic.

2. Benefits and risks associated with wearing face mask

2.1. Incidental benefits of wearing face masks

Currently, literature on mask usage is skewed towards its benefits. For example, this preventative measure, along with other mitigation strategies (physical distancing and hand hygiene) employed to reduce COVID-19, concomitantly led to a decline in influenza, enterovirus, and all-cause pneumonia cases in Taiwan (Chiu et al., 2020). Similarly, another retrospective study in China and Thailand also observed a decrease in the incidence of respiratory infectious diseases, both for viral and bacterial infections, during the pandemic (Hu et al., 2021; Ndeh et al., 2022). Granted, it is difficult to establish the independent and collective effects of the measures deployed that yielded this positive spill over. Hence, research needs to be conducted in that regard.

A subsidiary benefit of wearing facemasks has been a decrease in the exposure of wearers to particulate matter (PM) (Lin et al., 2021). Numerous studies allude to a positive correlation between PM levels with respect to the transmission and fatality rates of COVID-19 (Wang et al., 2020; Zhang et al., 2020; Zhu et al., 2020). Comunian et al. (2020) noted that the susceptibility and severity of COVID-19 symptoms in patient are linked to PMs ability to induce inflammation in lung cells. On the surface, it is tempting to dismiss this particular byproduct of mask usage on the grounds that anthropogenic emissions of $PM_{2.5}$ declined, especially during earlier waves of the pandemic. Even though a number of studies have been published confirming lower outdoor PM levels and higher indoor PM levels during the pandemic, that in itself does not discount the ability of masks wearing to limit exposure to these particles (Ezani et al., 2021; Mousavi and Wu, 2021).

In another study, Langrish et al. (2009) showed that volunteers who wore face masks were not subject to variability in blood pressure and heart rate due to air pollution. In accordance with the present results, in a later study, (Langrish et al., 2012) did a crossover trial on 98 patients with coronary heart disease in central Beijing. The results showed that wearing a highly efficient face mask reduced the symptoms of a range of cardiovascular diseases. In contrast to earlier findings, Cherrie et al. (2018) investigated the effectiveness of commercially available face masks in filtering particulate matter. Although all types of face masks studied showed some degree of filtration for particulate matter, the exposure reduction was not well acknowledged. Therefore, research focusing on quantifying exposure reduction from air pollutants is necessary to understand the benefits of face mask wearing by the public due to the COVID-19 pandemic. This is of utmost necessity in developing nations and megacities, where air pollution is a serious problem and causes various types of cardiopulmonary morbidities and is linked to mortality. Further research could also be conducted to determine the effectiveness of face masks in protecting the wearer from exposures to contaminants such as trace metal-bound particles, volatile organic compounds (VOCs), Polycyclic Aromatic Hydrocarbons (PAHs), and other air pollutants detrimental to public health.

2.2. Risk associated with wearing face masks

On the other hand, wearing face masks has associated dangers for the wearer. The mode of exposure is via dermal contact, inhalation, or both. Since face mask is made of predominantly PP (polypropylene), there is a risk of inhaling microplastics (Torres-Agullo et al., 2021). Moreover, the detachment of microsized fibers, fragments, and particles loosely attached to the inner layer of the face masks has been reported by Han and He (2021). These findings provide the following insights for future research: the level of microplastics inhalation of different face mask brands; assessing the accumulation of the pollutants using techniques such as nasal lavage and simulations with breathing thermal manikins; exposure risk via inhalation of different age groups; and the effect of face mask aging on the release of microplastics to the wearer.

Furthermore, a significant amount of VOCs, PAHs, alkanes, and phthalate esters were detected on face mask in a landmark study conducted by Jin et al. (2021). While diethyl (DEP) was found in all the face masks analyzed, DEP and di-nu-butyl (DBP) comprised 85% of phthalate esters. The face mask samples were collected from different countries, and all of them contained varied amounts of semi-volatile and volatile organic compounds. Naphthalene, classified as a possible human carcinogen by the US Environmental Protection Agency (USEPA) (EPA, 1998), was detected in all 60 face masks examined, representing 80% of the total PAHs amount. In the same vein, Xie et al. (2022) attempted to evaluate the presence and health risk of phthalates on 59 face mask samples collected from various countries, representing 56 brands. The study revealed that phthalate amounts ranged from 115 ng/g to 37,000 ng/g, where bis(2-Ethylhexyl) phthalate (DEHP), DBP, and diisobutyl phthalate (DiBP) were the most dominant ones. The estimated daily intake of phthalates was 33.9 ng/kg-bw/day, and the non-carcinogenic risk assessment showed it is within the safe limit. However, the cumulative carcinogenic risk 50 masks indicates an adverse effect to human health. This was significant in that it demonstrates the presence and the risk associated with phthalates on face masks. Similarly, Wang et al. (2022) investigated the presence of phthalates in 12 surgical masks. The study identified that phthalate levels ranged from 55 ± 35 to 1700 ± 140 ng/mask, where di-n-butyl phthalate (DnBP) and DEHP contributed 42–100% of the total mass load of phthalate esters. Moreover, a study conducted on 60 brands of surgical face mask from around the globe revealed that Naphthalene was the major (80% of total PAH levels) mask-borne PAH and acrolein was detected in all samples. Although the concentration of acrolein decreases over the wearing time, its mutagenic nature is a concern that requires in depth study (Jin et al., 2021). The abovementioned studies found varied levels and types of phthalate esters, which calls for further research to bring about a comprehensive understanding. Hence, there are a wide array of scenarios for further research. Most importantly, the effects of temperature, moisture, humidity, and breathing rate need to be explored in more detail by accounting for the age group as well as physical activity levels. Besides, Lee and Seo (2018) research on the factors affecting the release of DEHP from polyvinyl chloride (PVC) showed that the presence of airborne particles increased the release of VOCs by increasing the surface area available for absorption. More broadly, research is also needed to determine the effect of airborne particles on the inhalation influx of organic pollutants on face masks. To quantify the levels of trace elements in face masks, Bussan et al. (2021) analyzed 24 surgical face masks using breathing experiment and saliva simulation. Lead (13.33 g/g), Cu (410 g/g), Zn (56.80 g/g), and Sb (90.18 g/g) were found in a handful of masks. Surprisingly, 58% of Pb was leached by saliva simulations when exposed for six hours. Taking all the aforesaid into consideration, mask designers need to develop innovative masks that give priority to enhanced protection, are not prone to nanofiber and microplastics release, all without sacrificing comfort levels experienced by wearers. Moreover, safe levels of toxic chemicals in face masks need to be established for regulatory bodies to modulate the activities of manufacturers operating or trading within their jurisdiction.

Secondly, the overall exposure of semi-VOCs and VOCs contaminates can be higher if there is a secondary source, such as the level of organic contaminants in applied cosmetics and the surrounding air. These background sources of contamination can alter the physicochemical characteristics of airborne microplastics owing to their large surface area (Facciolà et al., 2021). Their large surface area favors surface oxidation, a process crucial to altering its affinity for other substances (e.g., metals and hydrophobic compounds) and the absorption of several types of contaminants (e.g., POPs) upon environmental exposure. Furthermore, environmental exposure brings about a difference in the adsorption affinities between virgin and old plastics. This means that research designs investigating the detrimental effect of microplastics inhalation in humans must go beyond using virgin materials as sources of microplastics and take into account the effect of environmental exposure on the properties of these particles. Risk assessment should factor in the plausible variabilities that exist on account of the contribution of environmental pollutants to the toxicity of microplastics. Previous studies on the inhalation of organic pollutants are based on one face mask per day to estimate the daily intake. However, this could be expanded to include the scenario of frontline workers who need to replace face masks several times a day. In addition, wearing double and triple masks is a common occurrence that needs to be accounted for in risk assessment. Lastly, the types of face masks assessed can be broadened to include other dominant brands widely used to obtain the overall levels of organic pollutants in face masks.

3. Conclusion

The COVID-19 pandemic has normalized the use of face mask by the general public. Consequently, donning of face mask has been associated with health benefits and unintended risks. The benefits range from limiting the spread of COVID-19 and other respiratory diseases such as influenza, measles, and pneumonia. In addition, exposure to particulate matter has been curtailed by mask wearing. In contrast, wearing face mask has increased the risk of inhaling contaminants such as microplastics, VOCs, phthalates, and PAHs. Considering the benefits and risks, research is needed to quantify the associated risk. Furthermore, more research should be tailored towards developing masks with minimal risk throughout product life cycle along with the maximal benefits of protection.

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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