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Effectiveness of Face Masks and Respiratory Aid Devices for Prophylaxis against COVID-19

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ABSTRACT: *The COVID-19 epidemic was spread rapidly around the world in 2019, and has greatly affected people's general interaction, their work habits, daily lives and businesses. A personnel protection against the spread of COVID-19 is not only beneficial but is critically important especially for those working in medical fields. Current studies were performed to review the use and benefits of face mask and respiratory aid devices in order to control the spread of COVID-19. The respiratory aids devices (RADs) may be recommended as anti-COVID-19 masks rather than surgical masks. However, RADs having P and R series filters do not prevent the infiltration of coronavirus due to its smaller size as compared to the filtration capacity of filters. The N99 and N100 filters cause a difficulty in breathing; it is difficult to wear such sort of respirators for a longer time. N95 respirators are recommended by medical professionals as they provide lesser (almost half) respiratory resistance. However, wearing of face masks is also involved some risks and side effects which may include physiological and disturbing effects, difficulty in breathing, affecting the volume and quality of sound, decrease of innate immunity, cardiopulmonary overload and increase in contamination chances due to development of humid habitat inside the mask.*

Keyword: *COVID-19, Epidemic, Virus, Respiratory aid devices, Face Masks*

INTRODUCTION

Currently, a lot of challenges are faced to the environment for which various suitable treatment technologies are being adopted (Ambreen et al., 2019; Rehman et al., 2019; Hussain et al., 2021) and widely investigated (Chaudhari et al., 2019; Iqbal et al., 2019; Ullah et al., 2019). The global outbreak of coronavirus disease 2019 (COVID-19) has affected every part of human lives and has shown numerous adverse effects on the climate and environment. The measures taken to control the spread of the virus and the slowdown of economic activities have significant effects on the environment. Other negative consequences of COVID-19 also include the disposal of gloves, masks and disinfectants and burden of untreated wastes continuously endangering the environment (Rume and Islam, 2020). The COVID-19 infections, caused by anovel coronavirus, were first time accounted for in December 2019 in the city of Wuhan, China (Hou et al., 2020). The World Health Organization (WHO) has described this disease as “serious intense respiratory plot COVID 2” (SARS-CoV-2) (Organization, 2020). WHO has announced the SARS-CoV-2 as a pandemic illness which is adversely affecting masses around the globe (Castagnoli et al., 2020). Particularly, old-aged people with affected immune systems are more prone to the disease caused by the coronavirus (Corse et al., 2020; Sinclair and Abdelhafiz 2020; Stankovska et al., 2020). According to the worldometer figures, the COVID-19 has reached to almost 223 countries of the world with 229,835,231 confirmed cases of infections and 4,713,636 reported deaths till September 21, 2021 (Annaka, 2021). People are using face masks and some other respiratory aid devices as a shield to keep themselves protected against the COVID-19. Mostly, face masks are fabricated from cotton and nonwoven fabric. The diameter of fibrous layer of the face masks is in the microns range (Li and Gong, 2015). Activated carbon is also being employed in different respiratory aid devices for the said purpose (Gupta et al., 2020; Rasheed et al., 2020).

Current studies were performed to overview the effectiveness of face masks and different respiratory aid devices to prevent the spread of COVID-19.

RESULTS AND DISCUSSION

Masks and respirators as protective tools against COVID-19

Due to their different resistance to the fluids, surgical face masks are categorized into 80, 120 and 160 mm Hg (Park, 2020). Surgical face mask is a loose fitting and a disposable device which provides a barrier and separation from the nose to mouth of a user and thus provides protection against the coronavirus (O'Dowd et al., 2020). Respirator is another medical device and is different from the mask. The respirators are fabricated from a non-woven fabric that is comparatively thick in size (Li and Gong, 2015). Respirators are utilized to sift out airborne particles such as microorganisms and thus infections by producing a seal around the nose and mouth. They are employed when viral and dangerous particles or fumes are present in the environment. The US National Institute for Occupational Safety and Health (NIOSH) has classified Sifting face-piece respirators (SFRs) into nine different categories(as shown in Table 1) (Dorman, 2014). Fig. 1 demonstrates the importance of using face masks to minimize the exposure to infectious aerosol particles (Chatterjee et al., 2020).

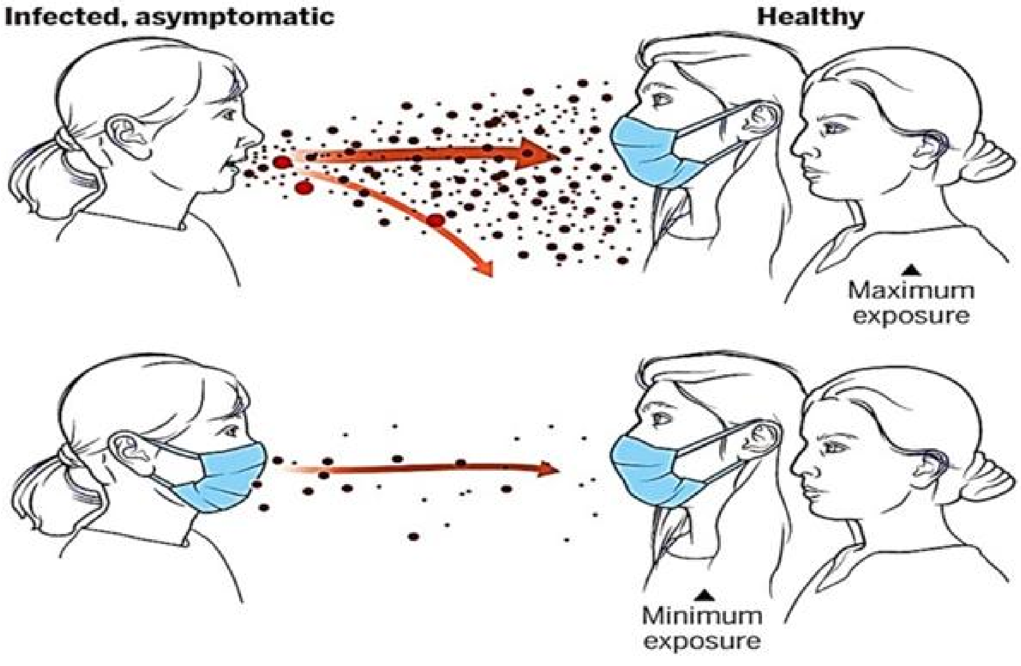

Fig. 1. Use of face mask helps preventing the spread of airbornetransmission of viruses (Chatterjee et al., 2020).

Depending on the aerosol type utilized in testing, filter series is divided into "N", "R", or "P" categories. A "95", "99", and "100" class efficiency is labeled against the 95%, 99% and 100% removal of aerosol particles. N-type filters are tested against a mildly degrading NaCl aerosol to ensure the protection of workers from solid particles. R-type filters are tested against a highly degrading dioctylphthalate (DOP) oil aerosol to check their resistance against liquid particulates. P-type filters demonstrate high resistance to degradation and are therefore examined against DOP until their performance (in terms of filter efficiency) reaches at its lowest (Safety and Health, 1995). The respirators present in N-series can filter up to 0.079 ± 0.020 µm particle size and the P-series and R-series respirators block the particles having size up to 0.180 ± 0.020 µm (Dorman, 2014).

Table 1: NIOSH's Certified Respirators (Dorman, 2014)

Respirator	Filtered particles of Aerosol	Contradict to Oily substances	Minimal Particle (µm)	Service Life (hour)
P95	93%	Strongly	0.180 ± 0.025	40
R95	93%	Weakly	0.180 ± 0.025	8
N95	93%	Do not	0.079 ± 0.025	8
P99	97%	Strongly	0.180 ± 0.025	40
R99	97%	Weakly	0.180 ± 0.025	8
N99	97%	Do not	0.079 ± 0.025	8
P100	100%	Strongly	0.180 ± 0.025	40
R100	100%	Weakly	0.180 ± 0.025	8
N100	100%	Do not	0.079 ± 0.025	8

Spreading phase of coronavirus

The COVID-19 is mostly transmitted through little droplets or aerosol, but in many cases the virus is transmitted by a direct interaction with contaminated surfaces or infected bodies (Feng et al., 2020; Zuo et al., 2020; Azimi et al., 2021; Ram et al., 2021). Both ways of transmission of COVID-19 are considered when personal protections are taken care of (Tang et al., 2006). WHO reported that sneezing of a patient yields up to 45,000 droplets nuclei having a diameter range of 0.4-13 µm size (Borak, 2020). Such a tiny droplet can be transmitted with the speed of 100m/s (Simonds, 2020). These tiny droplets come from a patient's mouth or nose by coughing or sneezing and transmit directly to ahealthy recipient (Sheriff, 2021).The transmission of droplets depends on their sizes and the distance between the recipient and the source. To minimizethe spread and transmission of coronavirus, a minimum of six feet distance is suggested between the source and the recipient (Tang et al., 2006; Chartier and Pessoa-Silva, 2009; Chigurupati et al., 2020).

A study by the National Institutes of Health (NIH) concluded that the COVID-19 viruses remain stable for a long time on the surface of aerosols present in the environment (Fears et al., 2020; Ren et al., 2020; Yang et al., 2020). The COVID-19 can also be transmittedthrough the eyes of an infected person (Chu et al., 2020; Manigandan et al., 2020; Sadhu et al., 2020). A dire need was felt for the detailed studies on the mode ofactual infection caused by the COVID-19 disease (Han and Yang, 2020).

Indications for the surgical face masks

Considering the situation of COVID-19 pandemic, a surgical face mask wearing must provide protection tothe followings (Worby and Chang, 2020):

- Persons having indications of respiratory infections and (or) confirmed COVID-19.
- Health care workers (HCWs), medical transport individuals and first-aid persons who somehow came into contact with any of the individuals mentioned above.
- HCWs having exposures to those with indications of respiratory infections.

In healthcare settings, the non-ill fraction of the population is not supposed to wear surgical masks to avoid from the above infections (Buckrell et al., 2020). Considering the spread of coronavirus and staying of population in isolation, the face mask wearing could provide an additional measure other than physical distance, hand hygiene and barrier measure (Bekele and Yitayih, 2020; Howard et al., 2021; Liao et al., 2021). In such situations, a standard cloth made mask is preferably used. A proper use of a mask by an asymptomatic person may reduce greatly the probability of virus transmission as a mask protects the wearer’s surroundings. However, the chances of infections are still there if a healthy individual comes into a close contact with a person having respiratory signs (Howard et al., 2020). Table 2 summarized the situations under which different surgical face masks are recommended by health professionals (Lepelletier et al., 2020).

Table 2: Surgical facemask suggested by medical professionals (Lepelletier et al., 2020)

Professionals	Care situation	Indicating for wearing mask	Types of Masks		
		Patient Infection Status	Patients	Professionals	
			Surgical	Surgical	FFP2
COVID-19[I]	Aerosol Generating Procedures (AGPs) and invasive care[II]	Symptomatic patients[IV] having symptoms	✓	✓	
Pharmacists		Patients having a risk of severe type of virus[III]	✓	✓	
Pharmacy dispensers		All symptomatic patients[IV] regardless of infectious status	✓	✓	
HCWs [I]	Simple procedures including	An infected patient having arisk of severe infection of COVID-19[III]	✓	✓	
	Consultations but excluding	Infected patients[IV] regardless of infectious COVID-19[III]	✓	✓	
	AGP sand invasive care[I]	COVID-19 patients			✓
	AGP sand invasive cares[II]	All patients having infection of virus	✓	✓	

[I]Doctors, dentists, nurses, midwives, masseur-physiotherapists, ambulatory medicine and medico-social establishments and in healthcare settings
[II]Non-invasive ventilation, bronchofiberscopy, tracheal intubation, endotracheal suction, invasive open expiratory ventilation, nasopharyngeal sampling, autopsy, aerosol therapy, aerosol-generating chest physiotherapy, causing sputum, etc.
[III]hypertensive, diabetic.
[IV]Respiratory infection symptoms: cough, sneeze, fever etc.

Effectiveness of surgical face mask against COVID-19

The face masks fabricated from non-woven material haveonly 33.1% filtration capacity against the particles ofsize 2.5 µm ($PM_{2.5}$). The size of coronavirus is almost 0.1 µm (Das et al., 2020; Wu et al., 2020; Klumpp and Poudel, 2021) which is approximately less than the size of $PM_{2.5}$. In addition, the Centers for Disease Control and Prevention (CDC) indicated that since these materials are not effective against SARS-CoV-2, therefore even a careful coveringcannot effectively prevent the virus from escaping (Wuthisuthimethawee and Khorram-Manesh, 2021).

Effectiveness of respiratory aid devices forCOVID-19

The respiratory devices having Pand R series filters do not preventthe infiltration of coronavirusdue to its smaller size as compared to the filtration capacity of filters. The N99 and N100 filters cause adifficulty in breathing; it is difficult to wear such sort of respirators for a longer time. N95 respirators are recommended by medical professionals as they providelesser (almost half) respiratory resistance (Paxton et al., 2020). Compared to ~ 36% of surgical masks, the filtration capacity of N95 is approximately 95% (Roberge, 2008). Another study found that the maximum inhalation rate through N95 can produce less than 90% of the filtration capacity of a 0.25 micron virus aerosols (Tcharkhtchi et al., 2021). In another study, it has been shown that the N95 masks are highly effective against *E. coli* T4 virus, bacteriophage MS2 and *Bacillus subtilis*. The size of MS2 ranges from 0.03 to 0.08 µm, where 0.1 µm represents the flow size of *E. coli* T4 and *Bacillus subtilis* viruses. The sizes of T4 and *Bacillus subtilis* are ideal for COVID-19 case studies. For a normal inhalation flow rate, Q (30 liters / min), the percentage penetration (PP) values for T4 and *Bacillus subtilis* are 0.23 and 0.58, respectively (Fig. 2 and Fig. 3). For heavy duty, the suction flow (85 L/min) of T4 and the PP value of *Bacillus subtilis* are 0.95 and 1.9, respectively (Mahdavi, 2013).

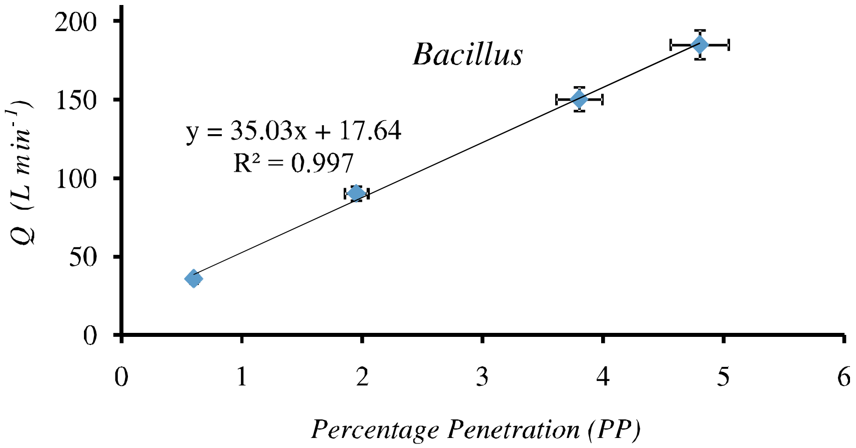

Fig. 2. A graph between the percentage penetration, PP and the inhalation flow rate, Q for *Bacillus subtilis* virus (Mahdavi, 2013)

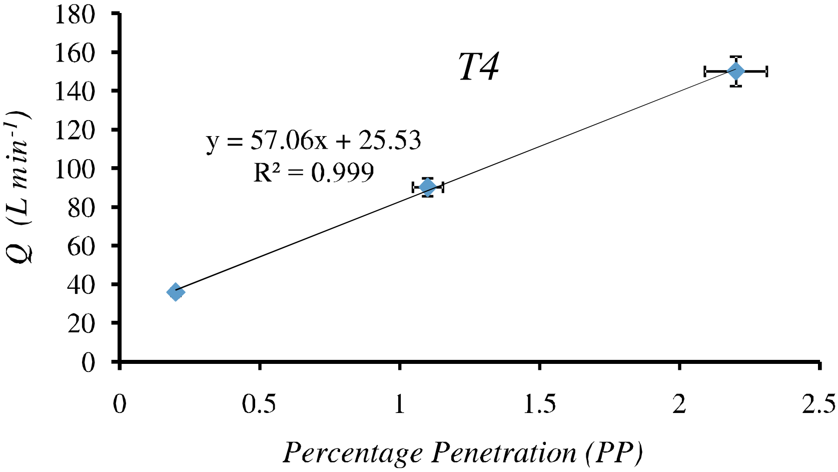

Fig. 3. A graph between the percentage penetration, PP and the inhalation flow rate, Q for the T4 virus (Mahdavi, 2013)

The average human respiratory rate is 60.9 g/min or 12 kg/day (Lepelletier et al., 2020). Statistical analysis is important when calculating PP based on average human respiratory rate. The regression line presented (Fig. 2 and 3) allows us to conclude that under normal rates of human respiration, penetration of *Bacillus subtilis* and T4 aerosols is not observed. However, there is no adequate clinical study on the safety of surgical and anti-COVID-19 masks, but another study has been concluded that such type of surgical masks was tested against influenza virus (which is similar to COVID-19). The department of Medical Research of Imperial University suggested that the use of such respirators or respiratory aids can reduce the possibility of COVID-19 disease (Ortiz-Prado et al., 2020). When a patient sneezes, 0.5 μm nuclear droplets are formed which, because their size is greater than the filtering capacity of the surgical mask, can penetrate the outer surface of the surgical mask due to their low filtering capacity (the filtering capacity of surgical masks is only 36%). On the other hand, respiratory aids have an ability to block virus aerosol particles, thereforethese respiratory devices may be recommended as anti-COVID-19 masks rather than surgical masks.

Sideeffects of wearing the face masks

With the important role of face masks in prevention of COVID-19, its use (wearing) is also associated with some health risks. The volume and quality of sounds between people wearing masks is affected and people may come unconsciously closer to each other. Moreover, the exhaled air may go into eyes due to face mask so an impulse is created to touch the eyes with hands. Consequently, if contaminated hands are touched with eyes, then infection chances are more increased. The face masks may also make breathing process difficult (Kyung et al., 2020). In addition to this, some exhaled carbon dioxide may also go back along with inhaled air into the lungs in each successive respiratory cycle. It may enhance the breathing frequency and as a result, the infected people wearing masks may spread more contaminated air; the enhanced breathing may also push the viral load deep into the lungs (Chen et al., 2018). When a person weaning the face mask continuously breaths then water vapors provided continuously by breathing may develop a humid habitat inside the mask, which may further increase the viral load and other infections as well as decrease of innate immunity (Potts et al., 2006). The use of face masks has also been reported to be associated with some physiological and disturbing effects. Studies were conductedon 100 healthy volunteers in a tertiary hospitalon September 2020 and January 2021. The individuals having smoking habit, cardiopulmonary disease and impaired walking, were not considered for this study. To evaluate the mask uncomfortableness, the persons with and without surgical masks were given a six-minute walking test (6MWT). It was demonstrated in persons wearing surgical masks during 6MWT that end-tidal carbon dioxide (EtCO2), heart rate (HR) and respiratory rate (RR) were significantly increased ($p<0.001$) whereas SpO2 level ($p=0.002$) and walking distance ($p<0.001$) were decreased. In Mask-Discomfort Questionnaire, itching ($p=0.001$), fatigue ($p<0.001$), odour, salinity, resistance, temperature, and humidity scores were enhanced after 6MWT with mask. It was concluded that cardiopulmonary overload may be caused by masks (Dirol et al., 2021).

CONCLUSION

From the above discussion, it can be concluded that the surgical face masks are not very effectiveto stop the spread of viral coronavirus. They can only be helpfulagainst bacterial infections and surgical wounds. The respiratory aid devices (including N95) offer low inhalation rate and therefore can provide a better shield against the spread of viral coronavirus. A use of full-face respiratory aid device is highly recommended in areas where the chances of spread of coronavirus are high (such as in hospitals and in other medical fields). Eye protection is also extremely important for the health field workers to avoid direct interaction with the infected bodies while dealing with such type of patients. The RADs having P and R series filters do not prevent the infiltration of coronavirus due to its smaller size as compared to the filtration capacity of filters. The N99 and N100 filters cause a difficulty in breathing; it is difficult to wear such sort of respirators for a longer time. N95 respirators are recommended by medical professionals as they provide lesser (almost half) respiratory resistance. However, wearing of face masks is also involved some risks and side effects which may include physiological and disturbing effects, difficulty in breathing, affecting the volume and quality of sound, decrease of innate immunity, cardiopulmonary overload and increase in contamination chances due to development of humid habitat inside the mask.

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