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Review Article

Face Masks Use to Avoid Airborne Contamination during COVID-19 Pandemic and Related Conditions: A Systematic Review

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Abstract

Background: The facemasks use has been discussed to prevent respiratory disease due airborne contamination. The aim of this study was to perform a systematic review about the face masks use to avoid airborne contamination during COVID-19 pandemic and related conditions, registered (PROSPERO-CRD42020198347) and performed according PRISMA.

Methods: PubMed, Embase and Scopus databases were used to collect data. Observational studies, published in 2020, and English language, were included. Two reviewers independently identified records through database search and reference screening and disagreements were resolved by a third reviewer. Six studies were included.

Results: The works investigated about the use of masks (different types) to prevent droplets dissemination with virus or bacterial suspension and decrease COVID-19 transmission routes, comfort, or temperature. The studies have moderate to critical risk of bias and the level of evidence is III-2.

Conclusion: It is recommended facemask use to prevent droplets from escaping airborne and infecting other people, although there are different percentages of protection and can be possible a discomfort related the use. Further clinical trials to the effectiveness of face mask to avoid airborne contamination during the COVID-19 pandemic and the factors interfering with their effectiveness should be conducted.

Keywords: Coronavirus; COVID-19; Masks; Protective devices; Risk

Introduction

The use of facemasks was introduced in 1987 during surgery procedure (1). The surgical masks are worn by healthcare workers, mainly surgeons, to avoid the exhalation of pathogens into the surgical field. Nowadays, the use of face masks to prevent respiratory disease due airborne contamination has been discussed (2,3).

Since some undesirable outbreaks, such as severe acute respiratory syndrome (SARS) in 2003 and the human swine influenza (H1N1), several research have been undertaken to find ways of controlling and/or reducing infections due to airborne pathogens and those caused by human-to-human contact. According to Wells (4), isolated droplets are emitted upon exhalation. Even more, some pathogens could be transmitted through the airborne route (5-8) and numerous droplets containing infectious particles (bacteria and virus) are released during coughing and sneezing (9,10).

In Dec 2019 (Wuhan, China) the coronavirus disease 19 (COVID-19), caused by the new coronavirus SARSCoV2 was described. This virus has been quickly spread in the entire world, leading to pandemic by SARSCoV2 (11-22). To avoid the dissemination and contamination of this virus, there are important simple strategy as handwashing and mask-wearing (23,24). The WHO published on 6 Apr 2020 a guidance advising concerning the use of facemasks to preventing transmission of COVID-19 (25).

For viral respiratory tract infections, the mechanism/route of transmission can be divided into three categories, namely contact and respiratory droplets that can be large or small. Transmission via small droplets or droplet nuclei is more commonly referred to as aerosol or airborne transmission. Large droplets vary in size (>10μm to <500μm) and can directly contaminate a person located near an infected person (i.e. the source) (26). This forms the basis of social distancing as an important preventative measure against transmission of COVID-19. The three separate routes of transmission imply different protection measures for their control, but they can nevertheless be combined into a single strategy (27). The droplets that exit through the mouth and nose play an important role in the transmission of the virus. It can be reduced by wearing a facemask, although this is usually more important in preventing airborne transmission.

The droplets containing viral particles can also contaminate the environment, which when touched can transmits the virus to non-infected people (indirect transmission by fomites) (Fig. 1). Hence, in this case, hand washing is the single most important preventative measure against transmission of COVID-19.

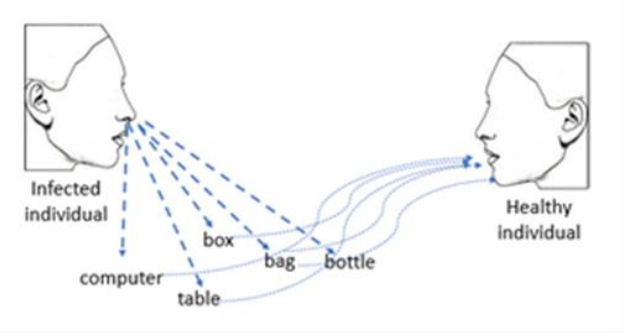

Fig. 1: The infected individual is sneezing, and droplets reach different objects (fomites) that a healthy individual can touch. The facemask used by the infected individual would avoid the dissemination of the virus

The number of droplets produced from a sneeze is 40,000 and from a cough 3,000. These are transported by expired airflows, affected by the human body plume and use of a facemask, as well as room airflow (28). Many infected individuals are asymptomatic or have no symptoms yet. If they wear a mask, this can prevent droplets carrying the virus from escaping and infecting other people. Barrier methods can be the first approach to fight against transmission of COVID-19 without the need to put on a mask. These include washing hands regularly; coughing or sneezing into elbow or tissue; using disposable tissue and throwing it away immediately into a bin; greeting without shaking hands; avoiding hugs. As a second

approach, specialized respiratory protective equipment (RPE) that provides the individual additional protection can be used (29,30). Understandably, COVID-19 pandemic has caused widespread panic and anxiety in people (31). Besides, the management of COVID-19 is difficult because there are many uncertainties about the virus, including transmissibility and virulence.

In additional to the (large) droplet route (probably the predominant route of transmission), there is debate about to what extent small droplets/aerosols, which can travel up to 8 meters from a sneeze or cough from an infected person (24), contribute to the spread of COVID-19, particularly as asymptomatic transmission occurs (unlike in influenza), and the virus infects both the upper respiratory tract (e.g. nose, sinuses, middle ear, throat) and lower respiratory tract (i.e. the lung). If aerosol transmission does occur, then appropriate infection control precautions should be taken particularly in hospitals, including respirator masks.

As drugs or vaccines against COVID-19 are not yet available, various non-pharmaceutical measures have been recommended to reduce the spread of infection, including hand hygiene and disinfection, improving environmental control, early detection and reporting, isolation, quarantine, use of personal protective equipment (PPE), as and the use of face masks, social distancing, and travel restrictions (Centers for Disease Control and Prevention (CDC), 2020. Thus, the aim of this study was to perform a systematic review about the face masks use to avoid airborne contamination during COVID-19 pandemic and related conditions.

Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines was used to base this review and the methods were prespecified in a protocol with the PROSPERO International Prospective Register of Systematic Reviews (CRD42020198347).

Research question

This systematic review aimed to answer the following question. The face masks are effective to avoid airborne contamination during COVID-19 pandemic and related conditions? The PICOS (P =Patients, I =Intervention, C =Comparison, O =Outcomes, S =studies design) method was used to define the five major components of the research question and they are described in Table 1.

Table 1: PICOS eligibility criteria

Criteria	*Inclusion*	*Exclusion*
P	General population during the COVID-19 pandemic	Individuals with diseases nonrelated to COVID-19
I	Masks use effectiveness	Interventions outside the pandemic and related to other diseases (non-COVID-19)
C	Without restrictions regarding comparison	-----
O	Droplet size distributions Emission of Respirable Pathogens	
S	Classical clinical trials, randomized, cross-over and randomized clinical trials, brief report.	Review, Meta-analysis, Case study, letters to the editor, short communication.

Legend: P: participants; I: intervention; C: comparison; O: outcomes; S: studies.

Search strategy used to find the publications.

Three independent reviewers accessed the PubMed, Embase and Scopus databases. The search was carried out on July 8th, 2020. The search

strings used in this review were ("face mask" or "face masks" or "mask" or "masks") and ("COVID-19" or "coronavirus disease" or "SARS-CoV-19"). All the pooled publications were screened following the inclusion and exclusion criteria. Reference lists of all potentially relevant articles and other reviews in the field were reviewed to identify any studies that were missed in the electronic database search.

Inclusion criteria

All the publications found in the databases were preliminarily considered included in this systematic review. To fulfill the inclusion criteria, the studies should include full articles, investigate the effectiveness of the masks on coronavirus or conditions related, during the actual COVID-19 pandemic, publication year 2020.

Exclusion criteria

As exclusion criteria, publications: (i) with findings not related to masks and other related condition.; (ii) published in a language other than English; (iii) editorials, letters, reviews being replies, abstracts, or short communications; and (iv) other pandemic phases were eliminated.

Methodological quality, risk of bias and levels of evidence (LE) of the selected papers

The publications were independently appraised by one reviewer, cross checked by a second reviewer and when there was disagreement, a third researcher was consulted, and the issue discussed until consensus was reached.

The level of evidence of each work was classified according to the National Health and Medical Research Council (NHMRC) hierarchy of evidence (Fig. 2) (32).

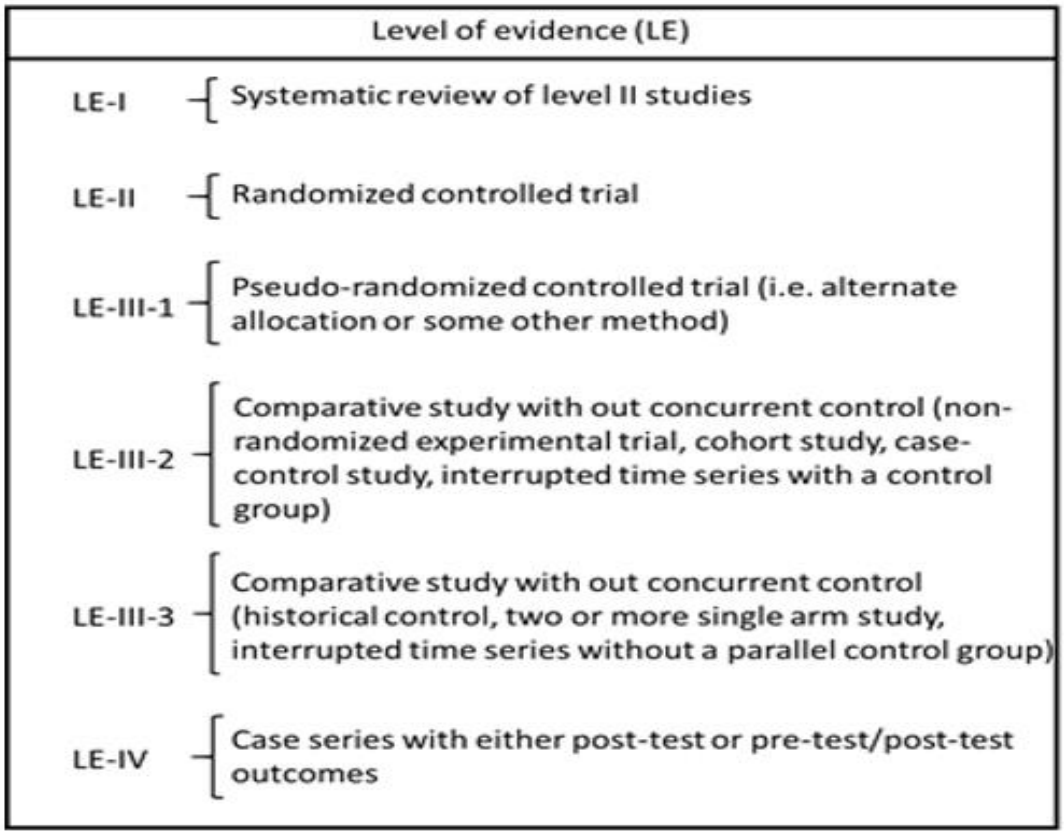

Fig. 2: Level of evidence adapted from NHMRC, 2009

The risk of bias of the included studies was evaluated using the ACROBAT-NRSI instrument ("A Cochrane Risk of Bias Assessment Tool for Non-Randomized Studies"), which compares the health effects of two or more interventions. ACROBAT-NRSI covers seven domains chronologically arranged pre-intervention, at intervention and post-intervention. Each item was qualified as low, moderate, serious, or critical risk of bias. It was needed to inform when no information was present. An overall risk of bias judgment based on the assessment of individual domains, with the most cited classification prevailing, however, in practice, some 'serious' risks of bias (or 'moderate' risks of bias) can be considered additive, so that moderate' risks of bias across multiple domains can lead to a general judgment of the 'serious' risk of bias (33,34).

Study selection and data extraction

All references found on the databases were exported to a data management software (EndNote X9), and the duplicates were removed by two authors. The review proceeded with two reviewers independently examining titles, abstracts, applied eligibility criteria, and selected the studies for inclusion in the systematic review (researchers were blinded to each other's decisions). The disagreements were solved by the analysis of a third author.

The data were extracted from each article and were imported to an excel spreadsheet containing: (i) data regarding study information (author and year), (ii) participants/groups (sample size, age, sex), (iii) virus, (iv) mask types, (v) experiments, (vi) aims, (vii) outcomes, and (viii) levels of evidence with National Health and Medical Research Council (NHMRC). One researcher realized this extract and another person checked the spreadsheet. The disagreements were resolved by a third reviewer.

Results

Studies Selection

For this systematic review, the chosen databases retrieved 77 titles. From these manuscripts, 25 were from PubMed, 18 from Scopus, and 34 from Embase. After removing duplicates, 75 studies were screened by titles and abstracts. Reviewers AC and AS made the first screening and a third reviewer worked on their discrepancies; after this procedure, 19 manuscripts were considered potentially relevant. The available articles were fully read after the manual screening on the included studies' references and only 6 met the inclusion criteria. Fig. 3 shows the flowchart used in the selection of the studies.

Studies Characteristics and Level of Evidence

Table 2 presents the studies characteristics and their respective level of evidence. The countries that published the selected articles were China (35-37), Italy (38), Brazil (39) and Poland (40). The publication year from the selected manuscripts was 2020, considering the COVID-19 pandemic period. The works included from 20 to 2,307 subjects (2,700 subjects) and two of them were experimental (35,39), without human beings. The studies from Hong et al., (36) and Szepietowski et al., (40) are surveys and Hong et al., (36) did not specify the mask types used by their sample; however, Szepietowski et al., (40) that investigated the masks comfort (itch), identified surgical, N95 and cloth masks within its respondents. Scarano et al., (38) also investigated masks comfort; however, the face temperature of the participants was measured. Scarano et al., (37) and the other studies investigated surgical masks (35,38), N95 masks (35,38) and homemade masks (35,39).

Table 2 also presents the selected articles in relation to their methodological quality, based on the NHMRC hierarchy of evidence. The level of evidence from all selected manuscripts was III-2.

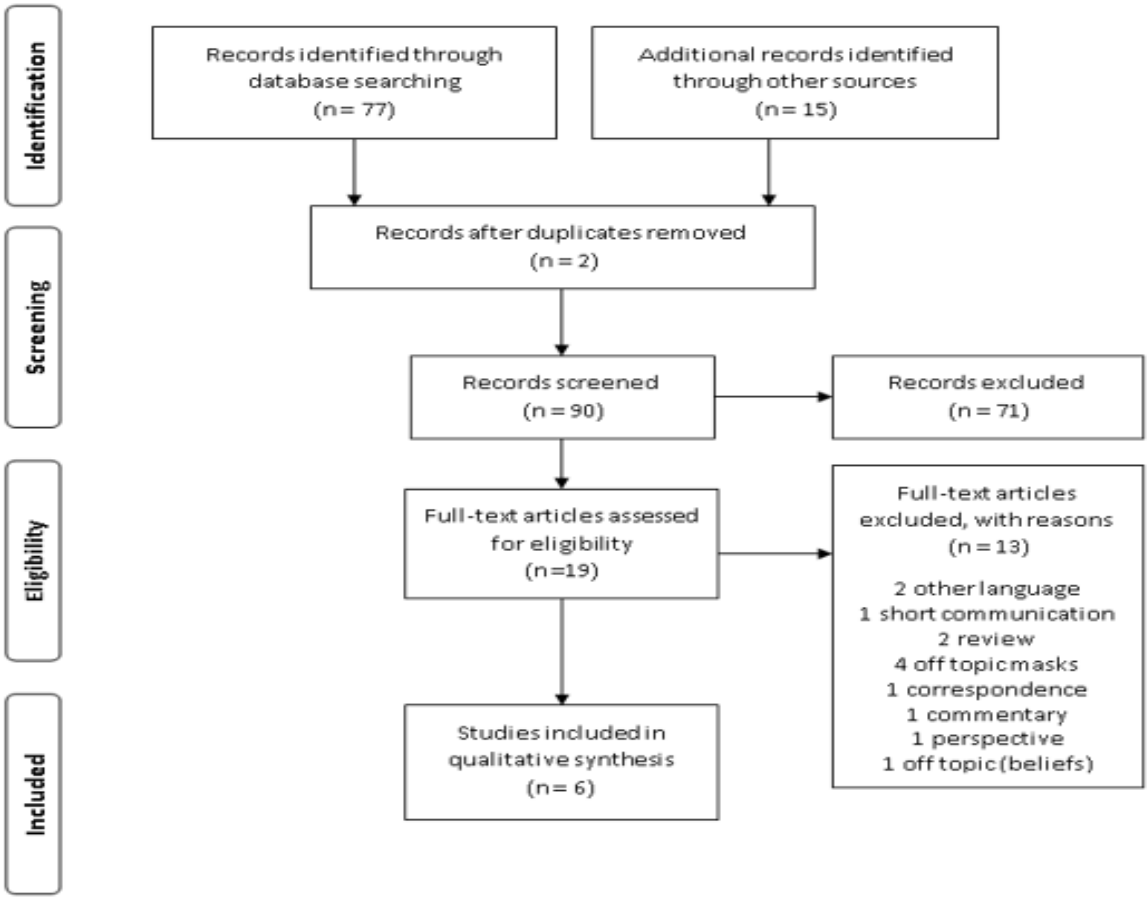

Fig. 3: PRISMA flow diagram of the selection process of the publications

Table 2: Description of the included manuscripts about masks efficiency during the COVID-19 pandemic

Author/Year	*Study type*	*Study goal*	*Comparison Group*	*Masks type*	*Participants (n; age; gender)*	*Results*	*Level of Evidence*
Ma et al., 2020 (34)	*Experimental	To investigate masks efficiency with avian influenza virus.	Three different masks were tested polyester cloth, N95 mask and homemade mask. A nebulizer was used to produce aerosols that was inhaled into and out of the syringes for 100 times through the synchronous piston movement of the four syringes, to mock human breath.	1.Medical surgical mask (polyester cloth) 2. N95 respirators 3.Homemade mask	NA	The N95 mask blocked 99.98% of the virus, the medical mask blocked 97.14% of the virus, and the homemade mask blocked 95.15% of the virus.	III-2
Rodriguez-Palacios et al., 2020 (38)	*Experimental	To investigate household textiles masks efficiency, quantifying their potential as effective environmental droplet barriers.	Single and double household textiles masks were tested with a bacterial-suspension spray simulation model of droplet ejection (mimicking a sneeze).	1.Household textiles masks, single layer 2.Household textiles masks, double layer	NA	All textiles reduced the number of droplets reaching surfaces, restricting their dispersion to <30cm as single layer and <10cm as double layer and area of circumferential	III-2

						contamination to ~0.3%.	
Scarano et al., 2020 (37)	*Observational transversal study	To measure facial skin temperature and discomfort when wearing protective face masks.	To compare the facial skin temperature and the heat flow when wearing medical surgical masks and N95 respirators.	1.Medical surgical masks 2.N95 respirators	A total of 20 subjects were recruited	N95 respirators are able to induce an increased facial skin temperature, greater discomfort and lower wearing adherence when compared to the medical surgical masks.	III-2
Hong et al., 2020 (35)	*Observational cross-sectional study	To investigate the transmission route, wearing masks or not, close-contact or exposure history of COVID-19 cases.	Epidemiological trajectory and clinical features of these COVID-19 cases, with or without the use of masks, were retrospectively retrieved and a survey was applied. 41 COVID-19 pre-symptomatic patients (13 without wearing masks and 28 is wearing masks) were analysed.	Not described.	127 patients (median age: 46 years; range: 11–80) with 71 male and 56 female	Pre-symptomatic patient mask-wearing and restriction of mass gathering in congested spaces particularly, are important interventions to mitigate the SARS-CoV-2 transmission. Data showed that incidence of COVID-19 was significantly higher for local residents close-contact with no mask-wearing.	III-2
Szepietowski et al., 2020 (39)	*Observational cross-sectional study	To verify the prevalence, intensity and clinical characteristics of itch related to the use of face masks by the general public during the COVID-19 pandemic.	The comparison groups were between the respondents scored into mild, moderate, severe or very severe itch.	1.Medical surgical masks 2.N95 + FFP respirators 3. Cloth masks	2,307 participants were included	Of the respondents, 60.4% reported using face masks during the previous week, and of these, 19.6% reported having itch. Responders who wore masks for longer periods more frequently reported itch. No difference in frequency of use the different types of masks.	III-2
Leung et al., 2020 (36)	* Diagnostic transversal study	To explore the importance of respiratory droplet and aerosol routes of virus transmission and potential efficacy of surgical face masks to prevent respiratory virus transmission.	246 individuals who provided exhaled breath samples; 122 (50%) participants were randomized to not wearing a face mask during the first exhaled breath collection and 124 (50%) participants were randomized to wearing a face mask.	1.Surgical face masks	Of these 246 participants, 111 (90%) were infected by human (seasonal) coronavirus ($n = 17$), influenza virus ($n = 43$) or rhinovirus ($n = 54$) and were analyzed.	Surgical face masks could prevent transmission of human coronaviruses and influenza viruses from symptomatic individuals. Coronavirus in respiratory droplets and aerosols in 3 of 10 (30%) and 4 of 10 (40%) of the samples collected without face masks, respectively, but did not detect any virus in respiratory droplets or aerosols collected from participants wearing face masks.	III-2

Interventions

All studies included a comparison group, comparing different types of masks (35,38-40) or comparing with and without the use of masks (36,37). The work goals and comparison groups are presented on Table 2.

Risk of Bias (RoB)

Regarding the overall Risk of Bias judgement, three publications have moderate RoB (36-38), the study of Szepietowski et al., (40) has serious RoB and two studies have critical RoB (35,39), according to our analysis based on the ACROBAT-NRSI instrument (Table 3).

Table 3: Consensus ACROBAT-NRSI judgments between two reviewers by domain of bias

Study	Domain							Overall RoB Judgment
	Bias Due to Confounding	Bias in Selection of Participants	Bias in Measurement of Interventions	Bias Due to Departures from Intended Interventions	Bias Due to Missing Data	Bias in Measurement of Outcomes	Bias in Selection of Reported Results	
Ma, et al., 2020 (34)	Critical	No information	Moderate	Moderate	Serious	Low	Low	Critical
Rodriguez-Palacios et al., 2020 (38)	Critical	No information	Moderate	Serious	Moderate	Low	Low	Critical
Scarano et al., 2020 (37)	Moderate	Moderate	Moderate	Low	Low	Low	Low	Moderate
Hong et al., 2020 (35)	Moderate	Low	Moderate	Moderate	Low	Low	Low	Moderate
Szepietowski et al., 2020 (39)	Moderate	Low	Moderate	Moderate	Moderate	Low	Low	Serious
Leung et al., 2020 (36)	Moderate	Low	Moderate	Moderate	Low	Low	Low	Moderate

Discussion

From the studies selected for this systematic review, four of them reported that, in general, the use of masks prevents droplets dissemination with virus (35) or bacterial suspension (39) and decreases COVID-19 transmission routes (36,37). Two works investigated the masks comfort, temperature, and itch, respectively (38,40). The investigations have moderate to critical RoB and the level of evidence is III-2.

Although vaccination is the first-line strategy controlling and preventing influenza A/H1N1 for older adults, PPE measures, such as wearing facemasks, are also important preventive behaviors to reduce the risk of becoming infected with influenza A/H1N1 during a pandemic (41).

Alternative public health strategies are required in the prevention and control of COVID-19 pandemic, as the social distancing, self-isolation at home, shoes, and clothes for use only outside the house, regular hand washing (and, if possible, washing everything brought into the house, such as cans, sacs, fruits, vegetables), and use of PPE, e.g., face masks.

The difference between large droplets (settle quickly within 1-2 meters) and small droplets (which can become airborne in aerosols and travel 7-8 meters) (24). These have implications regarding prevention: (i) large droplets transmission (most viral respiratory tract infections, including influenza and corona viruses), mostly contact precautions and handwashing is very important, and (ii) aerosol transmission (small droplets) (e.g. measles, chicken pox, open pulmonary tuberculosis) requires airborne precaution, e.g. respirator face masks (in hospitals in United Kingdom FFP3 and

in USA N95 & N99 face masks as opposed to the more commonly used surgical face masks), is strongly desired in addition to other precautions including hand washing and nursing patients in negative pressure isolation rooms.

There are various types of facemasks, manufactured and homemade, with different capabilities in protection against viruses. Some of them can eliminate more than 95% of the virus (35). Another study (39) investigated the efficiency of single, double household textiles masks exposed to a bacterial suspension, and they were considered effective environmental droplet barriers. The masks act as a physical barrier against infectious agents. However, universal facemask use in the community should be discouraged with the argument that this PPE probably provides no effective protection against COVID-19 infection (42). The WHO recommends face masks use for the public for the prevention of transmission of COVID-19 (25). Any important point in this consideration is also that face masks are usually incorrectly used by the public not fitted correctly (leaving gaps through which droplets/aerosols can escape), too much touching and fiddling of the mask during use-the front of which may become contaminated; and furthermore, the mask becomes moist/soggy with breathing. The discomfort rates, as itch and face temperature increase, can also decrease the masks efficiency (38,40). All of these contribute to reduce efficacy of the mask, indeed may increase risk of transmission/acquisition of infection, and thus could cause more harm than good.

Disposable surgical masks and their technical specifications were designed specifically for the protection of health-care workers during occupational exposures (37). Moreover, the transmission routes of COVID-19 were investigated with or without the use of face masks and they agreed that the face masks used are important to prevent the disease dissemination (36,37).

Various publications, using different methodologies, indicate that the use the face masks can contribute to reduce the disturbance worldwide due to the COVID-19 (35-37,39,43-46).

SARS-CoV-2 pandemic is increasing, and hospital systems are looking for intensifying the measures related to protect patients and health care professionals against this virus (46). The frontline providers are wondering about the relevance of the use of masks by health care professionals in this context.

Besides the use of face masks, other strategies have been suggested to avoid the dissemination of the COVID-19, such as hand washing (35,43,44), travel restrictions, daily government press conferences to inform and educate the population (46) and medical protective clothing (47). These strategies reinforce other important actions to minimize the transmission of the virus and ensure the maintenance of the physical, mental and psychological well-being of the population that is isolated and restricted, with (a) the practice of physical activity at home (48); (b) the use of technologies to maintain social and family life (49) and tools that promote mental balance (c), avoiding anxiety and depression (50), and (d) control of healthy habits related to sleep quality (51) and food (52).

The general use of masks is a well-established practice in Hong Kong, Singapore, and other parts of Asia and it has been practiced in a handful of U.S. hospitals (46). Nevertheless, it has been discussed whether the use of masks outside the health care institutions promotes a little, none, or a useful protection against the infection. The wearing of masks remembers about the invisible pathogen, but it is present, and can put in the mind of people the importance of social distancing and other infection-control measures. The absence of information about the clear transmission links and the non-specific symptoms at the early stages of COVID-19 challenged the conventional containment strategy considering the isolation and the quarantine (37). Masking, as a public health intervention, would possibly intercept the transmission link and the spread of the COVID-19. People wear masks for their protection from person-to-person contacts, but nevertheless, they

are also protecting each other through source control.

With the imminent pandemic, it is necessary to establish rapidly criteria to the adoption of mass masking to try to avoid possible confusion and chaos (37). However, as others (35, 43, (44) discussed, the strategy of hand washing is highly relevant to avoid the dissemination of the COVID-19.

The strengths of this review are the discussion about the use of facemasks to try to avoid the dissemination of the COVID-19 and related conditions, and the possibility of serving as an indication of the necessity of additional protection.

This study has limitations, particularly the absence of randomized clinical trials (RCTs), the small number of publications in general, the searches were performed only in three databases and in the English language.

Conclusion

Putting together all the considerations, in this fight against transmission of COVID-19 and related conditions, the use of a face mask (surgical, N95 or cloth masks) could prevent droplets carrying the virus from escaping airborne and infecting other people, although in different percentages of protection. Therefore, regardless of discomfort, temperature, and type of mask, they are used appropriately and judiciously. Further clinical trials to the effectiveness of facemask use to avoid airborne contamination during the COVID-19 pandemic and the factors interfering with their effectiveness should be conducted.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflict of interest

The authors declare that there is no conflict of interests.

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