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Masking during the COVID-19 pandemic – An update of the evidence

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Prepared by Juliette O'Keeffe

Introduction

Extensive debate over when, where, and what types of masks should be worn, and by whom, has persisted during the COVID-19 pandemic. Public health agencies around the world, including the World Health Organization (WHO),[1] continue to update their guidance as evidence emerges on the transmission of SARS-CoV-2, the virus responsible for COVID-19, and the effectiveness of mask-wearing for reducing transmission. Recommendations for wearing a mask in public have typically applied to areas where there is a high level of community spread of the virus and crowded locations where it is difficult to maintain physical distancing. The Public Health Agency of Canada (PHAC) recommends wearing a non-medical mask when in a shared space (indoors or outdoors) with people from outside your immediate household, or when advised by a local public health authority.[2,3] This advice may change as community transmission decreases across Canada and as rates of vaccination increase; however, mask use will remain an important public health tool to mitigate the spread of emerging SARS-CoV-2 variants, or new respiratory viruses in the future, and to continue to protect susceptible individuals from COVID-19.

The original version of this document published in April 2020 (updated October 2020), set out to explain the differences between commonly used **types of masks**, to review the literature on the **effectiveness of masks** for reducing transmission of respiratory pathogens, and to outline the **key considerations for the safe use of masks**. This document has been updated to incorporate new evidence across these core themes and to provide an overview of new evidence on the performance and risks associated with different **mask materials** (e.g., various fabrics and nanomaterials), **mask fit,** and **double masking**. This update has also been driven by emerging issues including potentially more transmissible COVID-19 variants and the need to understand the role of mask-wearing in reducing their transmission. This review does not constitute a systematic review of evidence but provides an overview and synthesis of key evidence and guidance available to date.

Types of masks

Masks are worn by individuals either to provide a barrier to the inhalation of particles (**protection of the wearer**), or to prevent the exhalation or release of particles from a sick person due to coughing, sneezing or other respiratory activities (**protection of others, or source control**). Masks can be used for medical and non-medical purposes, with key differences summarized in **Table 1.**

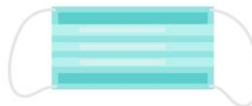
Medical masks

Medical masks include **respirators** (commonly referred to as N95s, or filtering facepieces (FFP)) **and surgical masks** that are certified to comply with standards of performance (e.g., NIOSH, ASTM 1, 2, etc.) and can be used in a healthcare setting. These face coverings provide protection against splash and sprays as well as respiratory droplets but differ in their ability to block smaller particles. Surgical masks are intended to block droplets emitted by the wearer or protect the wearer from exposure to droplets emitted by others. They are generally recommended for routine patient care. Respirators are recommended for use in care settings where aerosol-generating procedures are performed, and may be used in other settings when caring for COVID patients, if they are available.[1] Certified respirators that are properly fit tested are considered suitable for blocking both droplets and finer aerosols, with the respirator rating providing information on the proportion of aerosols that are blocked. For example, a National Institute for Occupational Safety and Health (NIOSH) approved N95 respirator is certified to block 95% of particles 0.3 µm and larger in diameter, compared to an N99, which can block 99% of these. Although respirators can provide a superior level of protection against small particles, this is partially dependent on proper fit testing to ensure a good seal between the respirator and the face. N95, N99, and N100 respirators are certified by NIOSH, which is recognized in Canada, although Canada has a national standard (CAN/CSA-Z94.4-18) for the selection, use and care of respirators, which is based on NIOSH testing and quality requirements.

Non-medical masks

Non-medical masks include homemade **cloth masks and other face coverings not intended for healthcare settings.** This can include disposable procedure masks that resemble surgical masks but lack certification of compliance with performance standards and are more likely to have ear loops rather than head straps or ties. The level of protection and source control provided by non-medical masks depends on the size and quantity of particles that are blocked by the mask and the amount of leakage between the face and the mask. The effectiveness of the mask is therefore affected by the **materials** used in construction (e.g., synthetic or natural fibres, varying thickness and thread count etc.), the **design** (e.g., conventional mask design, gaiters, bandanas, single or multi-layer etc.), and the **fit** (e.g., fixed or adjustable ear loops, head straps, ties, presence of a nose bridge). These characteristics vary widely for non-medical masks, as does the level of protection to the wearer or source control they provide.

Table 1. Overview of mask types

Respirator (e.g., N95, KN95, FFP2)	Surgical or procedure mask	Non-medical cloth mask
		
Construction		
• Typically, non-woven synthetic material such as polypropylene. • Various styles including cup, flat-fold, and duckbill, with and without an exhalation valve. • Most secured with a head strap although KN95s may have ear loops.	• Typically, 3-layer laminate structure of more than one type of material (e.g., non-woven air-laid paper and polypropylene).[4] • Surgical masks have ties; procedure masks have ear loops.	• Wide variability in fabric, number of layers and design. • 2- or 3-layer cotton being a common design for retail and homemade versions.
Settings		
• For use where exposure to aerosols is likely (e.g., N95s block 95% of particles of 0.3 µm and above). • For use where splash protection may be needed. Medical grade may be resistant to fluids such as blood, but commercial grade is not. • Valved respirators are not considered suitable for sterile environments.	• For use in routine care to reduce inward and outward transfer of respiratory droplets (e.g., block particles > 20 µm diameter and some finer droplet nuclei).[5] • For use against splash and sprays, blocking blood and infectious materials from contact with the facial area.	• For use by the public in non-healthcare settings as source control to reduce respiratory emissions from the wearer and to reduce exposure to respiratory emissions of others.[4,6]
Rating/approvals		
• US NIOSH for N95s or similar and EU standards for FFP equivalents.[7] • The Government of Canada lists approved alternatives to N95s.	• FDA with grading based on the level of resistance to splashing (e.g., ASTM 1 – 3). • **Note:** Many procedure-type masks found in retail outlets may not be assessed to any approval standards (non-medical masks).	• Not approved for use in any healthcare setting. • Not certifiable to any standard of effectiveness.
Advantages		
• Effective against droplet and aerosol penetration. • Can be reused and disinfected, with precautions.	• Protection against droplet and some aerosol exposure. • Disposable and inexpensive. • Fit testing is not required.	• Inexpensive and can be made from household materials for comfort. • Can be reused and washed.[8]
Disadvantages		
• Requires fit testing to achieve stated filtration efficiency. • May be uncomfortable to some wearers. • Expensive and may be in short supply.	• Less effective against smaller particles (e.g., 0.4-1.3 µm) due to leakage and looser fit compared to respirators.[9] • Not recommended for reuse or disinfection.	• Variable performance (filtration efficiency and breathability) depending on the materials, design and fit.[10]

Approaches to assessing the effectiveness of masks

The primary function of masks is to prevent exhaled infectious particles from a source from reaching a recipient either by preventing release (source control) or protecting an exposed person from inhalation of virus-laden particles or their deposition on facial mucosa. Masks assist the physical removal of particles from the air by interception, inertial impaction on a surface, electrostatic attraction, diffusion and other physical removal mechanisms, which may vary by particle characteristics (e.g., size, shape or charge).[11,12] Multiple approaches are used to assess the protective effect and source control performance of masks, ranging from experimental studies that quantify the physical removal of particles by measuring the filtration efficiency (FE) of materials, to studies involving human subjects that measure differences in clinical outcomes (e.g., levels of infection) based on mask-wearing scenarios.

- **Experimental studies**, often performed in a laboratory, provide information on the physical properties of mask materials. They can assess the **protective effect** or **source control** by quantifying the movement of particles of varying sizes either from the external environment through mask material into the breathing zone of the wearer or vice versa during different respiratory action (e.g., breathing, coughing, etc.).[6,10,11,13-27] Many of these tests use a simulated aerosol/droplet, such as a nebulized NaCl solution, and may use mannequin heads as the source or the exposed subject. Some tests may also use human subjects to measure particle release while performing different respiratory actions.
- **Observational studies** assess the effect of mask-wearing by observing clinical outcomes for mask wearers in different conditions or specific environments compared to non-mask wearers. They may also assess the effect of various mask-wearing behaviours such as length of use or type of mask use but do not introduce an intervention and can be retrospective in nature.[28-33] Observational studies can also be **ecological**, comparing observations at a community or population level, such as estimating the effect of mask mandates on case numbers in a geographical area or job sector.[34-38]
- **Controlled trials** observe the clinical outcomes for a control group (e.g., no masks) compared to an intervention group (e.g., respirator wearers). Examples include studies assessing the reduced incidence of clinical respiratory illness (CRI), influenza-like illness (ILI) or laboratory-confirmed respiratory illness (LCRI) among healthcare workers (HCWs) randomly assigned to different mask-wearing groups.[39-47]
- **Reviews** provide an overall assessment of the available literature, based on the quality of studies and the identified outcomes. Systematic reviews differ in their scope and inclusion and exclusion criteria. Some will only include randomized controlled trials, or certain settings (e.g., healthcare versus community), whereas others may include a broader range of studies. Thus, the outcome of reviews may differ depending on the specific research question and the studies selected for review.[48-54] Accompanying meta-analyses may pool results from multiple studies.

In assessing the effectiveness of masks for reducing transmission of respiratory viruses, multiple pieces of evidence such as those listed above are considered to provide an overview of both the types of materials and features of masks that provide the best barriers to particle movement, as well as the observation of how masks are used, and the effectiveness for reducing infection rates in various scenarios. The following section provides an overview of some of the key evidence on the effectiveness of masks for reducing transmission of respiratory viruses.

Evidence for the effectiveness of masks for reducing transmission of respiratory pathogens

Respirators (e.g., N95, KN95, FFP2):

There have been many studies that have assessed the properties of different mask types and various materials for blocking the passage of particles. Respirators that are certified to comply with NIOSH or equivalent standards of performance (e.g., N95s (USA), KN95s (China), P2s (Australia/New Zealand), FFP2s (Europe) and others) are rigorously tested under accredited laboratory conditions and provide a superior level of filtration of particles, including aerosols, compared to surgical and non-medical masks.[7,14,55] While their primary purpose is to provide a protective effect to the wearer, they are also found to be effective as source control, reducing release of respiratory particles from the wearer.[56] Multiple studies comparing the filtration efficiency (FE) of various mask types confirm the superiority of certified respirators over other types of masks for blocking the movement of small particles.[20,22,55-59]

Several ***observational studies*** have indicated a protective effect from the wearing of respirators. A retrospective study of a group of 493 healthcare workers (HCWs) in Wuhan, China, found that none of those wearing N95 respirators (278) working in a high-risk environment and observing regular hand hygiene were infected with SARS-CoV-2 compared to 10 of 213 staff working in a much lower-risk environment and not wearing masks and only washing hands occasionally.[28] The protective effect of respirators for HCWs exposed to SARS-CoV-2 during aerosol-generating procedures has also been observed.[60] Some case accounts of COVID-19 exposure events in healthcare settings where either masks or respirators were worn indicate a similar protective effect for masks and respirators; however, these studies were limited in their wider applicability given the small number of subjects involved.[31,32]

In ***controlled clinical studies***, the evidence for the superior protective effect of respirators over masks is mixed. Most studies have been based in healthcare settings and have assessed the effect on influenza-like-illness (ILI), clinical respiratory illness (CRI) or laboratory-confirmed respiratory illness (LCRI). Some studies have indicated a greater level of protection for respirators as compared to surgical masks, whereas others have found no significant difference. A cluster randomized clinical trial (RCT) of 1441 HCWs in 15 Beijing reported reduced incidence of CRI in N95 wearers compared to surgical mask wearers.[43] Another cluster RCT of 1,669 HCWs, also in Beijing, found that continuous use of N95 respirators was more efficacious against CRI than intermittent use of N95s or medical masks.[44] In contrast, other studies reported no significant difference in the incidence of laboratory-confirmed influenza among healthcare workers wearing N95s versus medical masks.[47,61] There are few studies that have looked specifically at the protective effect of respirators versus masks in the context of the COVID-19 pandemic. A review of mask use in healthcare settings for reducing spread of COVID-19 by the UK Scientific Advisory Group for Emergencies (SAGE) considers that, despite moves towards recognizing the potential for aerosol spread of COVID-19, full airborne precautions (e.g., universal respirator use) are considered to be impractical and likely unnecessary except in high-risk settings (e.g., during aerosol-generating procedures).[62]

Several ***systematic reviews and meta-analyses*** have reported mixed findings for the effect of N95 respirators versus surgical masks on reducing respiratory infections. An early review by Jefferson et al. (2011) reported that mask-wearing reduced respiratory illness in healthcare and community settings, with N95s providing superior protection over surgical masks.[63] A systematic review and meta-analysis by Offedu et al. (2017) also found that, compared to masks, N95 respirators conferred superior protection against CRI and laboratory-confirmed bacterial (but not viral) infections or ILI. Other systematic reviews/meta-analyses have found no statistically significant difference in ILI between healthcare workers using N95 respirators versus surgical masks.[64] A subsequent update of the 2011 review by Jefferson et al. in 2020 reported no clear difference between surgical masks and respirators in healthcare settings when used in routine care.[65] Chou et al. (2020) reported that while N95s and surgical masks had a similar level of effect for ILI, N95s may have been associated with a decreased risk of SARS compared to surgical masks.[66] A review by MacIntyre and Chughtai (2020) reported that continuous wearing of respirators by HCW was found to be protective, but intermittent use was not, and medical and cloth masks had less effect.[51] Bartoszko et al. (2020) found that surgical masks offered a similar level of protection to N95 respirators against respiratory viruses in non-aerosol-generating healthcare settings.[50]

Surgical/procedure masks

Experimental studies of other types of medical grade masks (e.g., surgical masks) find that surgical masks provide a protective effect against droplets and some aerosols. Early studies found that surgical masks could block about 60% of particles but may allow penetration by very fine particles in high concentration environments.[14,16] As source control, surgical masks can block the release of large droplets and some aerosols, and in many tests they perform better than most cloth masks, but are found to be less effective when compared to properly fitted respirators.[6,10,11,13-15,17,55,67]

Performance of surgical masks for the blockage of aerosols can range from one product type to another, which may be related to mask materials or fit of the mask.[68] More recent literature has expanded the testing and comparison of surgical masks to include more products, different types of fittings and testing with a wider range of aerosol sizes (e.g., < 5 µm in diameter). Clapp et al.

assessed the performance of various mask types against particles of 0.06-0.14 µm in diameter and found that a surgical mask (with ties) had a fitted FE of 71.5%. Tests of medical procedure masks with different types of fittings or modification ranged from 38.5% (fitted with ear loops) to > 80% (nylon hosiery fitted over mask).[22] Mueller et al. found that of three surgical masks tested, the mean removal efficiency for particles < 0.3 µm in diameter was between 50-75% when worn as designed and increased to 86-90% when fitted with a nylon overlay.[69] Pan et al. measured FE of surgical masks to be between 50-75% for particles 0.04-1 µm in diameter but 90% or better for larger aerosols (2 µm).[27] Hao et al reported a FE of about 50% for surgical masks for particles < 0.3 µm, and > 65% overall.[70] These studies all suggest that despite being primarily designed for the blockage of large droplets, most well-fitted surgical masks also provide some protection against aerosols.

The protective effect of surgical masks has been demonstrated in ***observational studies*** in healthcare settings. A retrospective study of SARS-CoV-2 infection among HCW in a US hospital before and after the implementation of universal masking with surgical masks for HCWs and patients found that masking was associated with a lower rate of infection.[29,47] In a case report from China, 41 HCWs were exposed to aerosol-generating procedures for a patient who subsequently tested positive for SARS-CoV-2. None of the HCWs, of whom 85% wore surgical masks and 15% wore respirators, tested positive for SARS-CoV-2.[60] A retrospective study of secondary attack rate (SAR) in a healthcare setting where the use of surgical masks was required by visitors and HCWs found a reduced incidence of respiratory viral infections among patients, indicating a source control effect of masks.[71]

In non-healthcare settings, several studies in France, Germany, Hong Kong, China and Australia have assessed the effectiveness of wearing surgical masks in the home by patients with influenza or ILI to reduce secondary transmission to other members of the household. Some of these studies have found a lower SAR, but did not show statistically significant reductions in infection,[40,45,72] including one study that assessed the protective effect of both surgical masks and N95-equivalent masks.[73] The greatest reductions in SAR have been observed in studies where mask-wearing was implemented early after the onset of symptoms in the sick patient, or where mask-wearing was combined with other measures such as hand hygiene.[39,41,46]

Cloth masks

The materials used in the construction and design of cloth masks vary significantly as does performance of these non-medical masks. The widespread use of cloth masks among the public during the COVID-19 pandemic has led to a substantial increase in the number of studies assessing the performance of different materials and mask designs, with the vast majority of these being ***laboratory studies assessing the FE of a range of materials***. Experimental studies find that performance is affected by the fit and the type of material used. Particle efficiency varies widely, being anywhere from < 5% to > 90%, depending on the type of material, layers and the fit.[10,11,19,23,27,69,70,74,75] While many household materials have been observed to have a high efficiency for blocking large particles, only a few perform well for smaller particle sizes.[11,19,27] Cloth masks with loose-fitting designs (e.g., handkerchiefs) and porous and lower weight fabrics are generally less effective at blocking the release of aerosols.[6,10,17,67,70]

Advice on making a homemade cloth mask suggests adding at least two layers of tightly woven fabric.[76] Layering of fabrics has been shown to have mixed results depending on the material type and size of particles assessed. For example, Clapp et al. found that the FE for aerosols (0.06-0.14 µm) of a three-layer cotton mask was just 26.5%, compared to 79% for a two-layer nylon mask.[22] Pan et al. found that adding a second layer of material (cloth bandana) improved FE for 2 µm particles from < 40% to 75%, but Hao et al. found that layering fabrics with a very low FE (e.g., a wool scarf and a cotton bandana) provided minimal FE even when tested as four layers.[23,27] Adding multiple layers may provide some improvement in FE but may also reduce breathability.[10,14] The most effective multi-layer designs use layers of different materials, such as absorbent layers and water repellent outer barrier layers (e.g., synthetic materials such as polypropylene and polyester).[77] Fabrics that allow for electrostatic interaction such as polyester and silk can provide superior removal compared to cotton, but breathability of fabrics can be a trade-off for filterability.

In additional to filtration studies of different fabrics, ***laboratory studies have also assessed the release and exposure to particles under different masking conditions***. Lindsley et al. observed that masking of both the source and the exposed person reduced exposure to aerosols regardless of the orientation and separation distance between them.[18] Stephenson et al. found that for droplets of 0.1-200 µm (median 27 µm) all mask types (cloth, surgical and face shield) reduced droplet exposure.[78] One experimental used SARS-CoV-2 containing droplets and aerosols in a controlled environment, wherein mannequin heads were used to simulate the effect of mask-wearing on an infected and an exposed subject with either both unmasked, one masked or both masked.[79] Both a protective effect and a source control effect were observed for the mask wearer for all mask types (cotton, surgical masks and N95 respirators). The cotton mask reduced exposure to the virus (protective effect) by 20-40% compared to the N95, which reduced exposure by 80-90%. The source control effect was larger, with the cotton and surgical mask blocking >50% of the virus and the N95 providing near complete blockage. No masks, including medical grade masks, completely blocked 100% of all viral exposure, but the exposure decreased with distance between the source and the exposed subject and when both the source and exposed subjects wore a mask.[79]

Cloth masks are not recommended for healthcare, or high-risk settings, but may be effective in community settings where there is a high level of adherence to mask-wearing. In ***observational studies***, the effect of cloth mask-wearing has been evaluated in workplaces and the community, although most of these studies provide limited details on the type of mask worn (e.g., materials, layers, fittings). Additional epidemiological evidence points towards the use of masks reducing the spread of the virus.[29,80,81] A study of mask-wearing among meat processing plant workers found that the incidence of COVID-19 was reduced in 62% of facilities following the implementation of universal mask-wearing and physical barriers. The study found that adherence to good mask-wearing practice varied, with up to 50% of the staff wearing masks below their noses at some sites.[82] Elsewhere, studies by Doung-ngern et al. and Hong et al. found that contacts of pre-symptomatic cases that wore masks were less likely to become infected with SARS-CoV-2 compared to those who did not report wearing a mask. Hong et al. reported that the incidence of COVID-19 among close contacts of pre-symptomatic COVID-19 patients was 19.0% for non-mask wearers compared to 8.1% for mask-wearers.[33,83] A widely reported case report of a hair salon with universal masking requirements in place found no onward transmission to 139 clients who had been in close contact with two stylists who tested positive for COVID-19.[84] Four close contacts living in the same home as the first stylist, where masks were not worn, tested positive for the virus.

There are few ***controlled trials*** that have assessed the effect of cloth mask-wearing on reducing respiratory viral infections. One study assessing the protective effect of cloth masks in a healthcare setting in Vietnam prior to the COVID pandemic found that the incidence of CRI, ILI and viral infections was higher among cloth mask wearers compared to surgical mask wearers.[42] A randomized control study to assess the effect of mask-wearing on reducing the spread of COVID-19 in the community (DANMASK-19) was carried out in Denmark, where there was a low level of mask-wearing among the general public at the time.[85] The study found no statistically significant difference in the COVID-19 infection rate for mask wearers compared to non-mask wearers; however, there was a high level of uncertainty in the final results.[85] The study found that there were varying levels of adherence among the study participants, with less than 50% of mask wearers wearing masks as recommended.

At a community level, ***ecological studies*** suggest that the rollout of universal masking requirements in public spaces is associated with decreased transmission and mortality associated with COVID-19. Leffler et al. found that average mortality due to COVID-19 was lower in the majority of countries with early adoption of mask-wearing in the community compared to countries without early adoption of mask-wearing.[86] Modelling studies have estimated that universal mask-wearing mandates reduced cases or the growth rate of COVID-19 in locations such as San Francisco,[36] a selection of US states,[35,87,88] the City of Jena and other cities with high population density in Germany,[89] and Morocco.[90] A more recent study identified a decrease in daily COVID-19 cases and a decrease in the growth in death rate within 20 days of mask mandate implementation across a large study of US counties.[38] Other models estimate that mask use can suppress transmission of COVID-19, but the effectiveness may be more significant where there is widespread adherence, minimized interactions between masks wearers and non-mask wearers, and widespread use of other complementary public health measures such as hand hygiene and distancing.[91,92] Modelling results from a survey of over 8000 Chinese adults found that mask-wearing provided the most protective effect from COVID-19 infection among four non-pharmaceutical interventions (NPIs - hand hygiene, respiratory etiquette, social distancing and mask-wearing), and the effect was increased where additional NPIs were used.[37] Emerging research is considering the effect of mask-wearing on severity of infection, including the rate of asymptomatic infection. Further research is needed to understand the relationship between mask-wearing, infectious dose, and severity of disease.[93,94]

Overview of systematic reviews

The evidence for the effectiveness of masks as source control or personal protection of the wearer is diverse in nature, ranging by study type, mask types, and settings. There have been several systematic reviews by researchers that have attempted to pull together the evidence on the effectiveness of face masks for reducing the spread of respiratory viruses, and many reviews carried out by public agencies to inform masking policy.[48-54,63-65,95-104] The key findings of these reviews vary due to differences in the scope and inclusion criteria of the reviews. A range in the degree of protective effect is reported depending on variables such as the setting (healthcare versus community), mask type (respirator, surgical mask or cloth mask), the mask wearer (infected versus susceptible), the range of respiratory viruses considered (influenza, ILI, H1N1, coronaviruses, SARS-CoV-2), and whether mask-wearing is combined with another protective measure such as hand hygiene.

Some ***systematic* reviews** find that mask-wearing is associated with a decreased risk of respiratory infection in the community,[51,53,103] or both community and healthcare settings.[48,52] The results from Chaabna et al. find a beneficial effect of medical facemask use when combined with other preventive measures, but cannot conclude the same for cloth masks or quantify the effects on SARS-CoV-2 transmission in community settings due to limited evidence.[53] MacIntyre and Chughtai also find that mask-wearing is enhanced when combined with other measures such as hand hygiene.[51] Brainard et al. find that there is evidence of a slight reduction in the odds of ILI infection, but overall the quality of evidence is low, and results varied by whether the ill or healthy person wears a mask, or if both wear masks (larger reduction in transmission).[95]

Other reviews indicate insufficient evidence, or no significant reduction in transmission of influenza or ILI with the use of face masks. Some of these studies are limited to randomized control trials (RCT) and influenza or ILI.[65,104,105] Dugre et al. found that mask-wearing by the public did not reduce CRI, LCRI, or other respiratory viral infection, but pooled evidence from two studies identified a significant protective effect on mask-wearing in university dormitories for ILI.[106] Brainard et al. note that RCT likely underestimate the protective effect of mask-wearing, while observational studies overestimate it. This may be due to other confounding factors among persons who wear masks, such as being more likely to undertake other risk-reducing behaviours.[95] Coclite et al. report that while there is evidence for masks reducing infection risk compared to no masks, statistical significance was not found in the controlled trials reviewed. Despite this, evidence from other types of observational and modelling data indicate a beneficial effect of face mask use in the community.[107]

A living review by Chou et al. originally reported no difference for different mask types compared to no mask for non-coronavirus respiratory illness in the community, but a possible decreased risk for coronaviruses (SARS and MERS).[96] Subsequent updates to this review provide some evidence of a small reduction in risk for SARS-CoV-2 for mask use versus no mask use in the community, but the strength of evidence remains low based on a small number of studies.[96]

Due to the paucity of randomized control trials for assessing the effect of mask-wearing and SARS-CoV-2, the systematic reviews that focused ***solely on SARS-CoV-2*** are based on a limited number of studies. A systematic review and meta-analysis by Li et al. found that mask-wearing was associated with a significantly reduced risk of COVID-19 infection, albeit based on a small number of case control studies.[108] Another systematic review by Tabatabaeizadeh, of which three of the four studies were also reviewed by Li et al., found that face-mask use is associated with a reduction in COVID-19 infection.[102] Rodhe et al. reported in a rapid review of observational studies on mask use and SARS-CoV-2 transmission in community settings that wearing face masks may reduce the risk of transmission, although noting that the quality of evidence from some studies is low.[109]

A review of the masking literature and recent systematic reviews by Abboah-Offei et al. reports that mask use provides more protection than not wearing a mask, and could be associated with a lower risk of respiratory infection.[54] N95 masks were found to provide more protection when used continuously compared to other mask types, but the protective effect can be limited by discomfort and poor fit. Fit and adherence to mask use are important to preventing transmission, and adherence was found to be low in the intervention groups in studies that reported it.[105] The absence of reporting on observations or measurement of adherence to mask-wearing, and details about the settings assessed (high or low-risk of exposure), limits a full evaluation of the outcomes of some studies. These variables may be important to understanding whether the measured effect, or lack thereof, of mask-wearing is influenced more by the mask itself or mask wearer behaviours and the environment.[110]

While there is some disagreement among the results of systematic reviews on the degree of effectiveness of masks for reducing transmission of respiratory viruses, on balance, most systematic reviews indicate some benefit from mask-wearing.[99,100] The evidence of a protective effect appears to be stronger in observational studies as compared to RCTs, which may be based upon the paucity of RCTs for mask use in community settings, and the small sample size used in some studies.[95] Evidence for SARS-CoV-2 is also still emerging, yet initial reviews based solely on assessing COVID-19 transmission risks indicate a likely benefit from mask-wearing.

Additional considerations for mask use

This section will provide an overview of some of the key considerations for effective mask use, such as the influence of **fit** and the **materials (including nanomaterials)** used in construction on FE, the effect of using a **double mask**, **exhalation valves** or a **face shield**, consideration for **decontamination and reuse** as well as **expired, counterfeit and recalled masks**, and special consideration for **mask use in children and persons with disabilities**.

Mask fit

Mask fit has a significant impact on the FE of masks.[69,111] The fit can be affected by the mask size and shape, the presence of a nose bridge, and how the mask is held onto the face (e.g., ear loops, head straps, or ties). Where respirators are used as PPE, a **fit *test***, and user **seal check (or fit *check*)** are essential for ensuring respirators (e.g., N95s) work as they are intended to. Fit tests are used to confirm that a specific make, model, and size of respirator provides adequate respiratory protection to the user by providing a tight seal between the facepiece and the face that prevents leakage into or out of the respirator facepiece (**Box 1**). If the respirator does not pass a fit test, another make, model or size is fit tested until a suitable respirator is found. The wearer can then use the same make, model, and size of respirator, repeating the test once per year to confirm that fit is maintained, or reconfirming fit if physical changes to the face have occurred, such as weight loss or injury. If the user changes the make, model or size of respirator, a new fit test is required.

Box 1: How is a fit test done?

A fit test can include either a **qualitative** or **quantitative** test and usually takes about 15 to 20 minutes to complete, during which time the wearer may perform various movements (e.g., turning head side to side or moving the head up or down). If the wearer normally uses a respirator in combination with other PPE, such as goggles or a face shield, these should also be worn during the test. The wearer should also perform a seal check before starting the fit test.

- **Qualitative** fit testing assesses whether the mask wearer can detect the taste or smell of a substance introduced into a chamber placed over the mask wearer. Common substances used in qualitative fit tests include isoamyl acetate (banana smell), saccharin (sweet taste), Bitrex™ (bitter taste) or irritant smoke, which causes coughing.
- **Quantitative** fit testing uses instrumentation with a fit testing adaptor and probe that is attached to the face piece. The instrumentation can measure generated aerosol, ambient aerosol, or controlled negative pressure and will compare the conditions inside and outside the respirator to determine a fit factor.

A demonstration of fit testing by the US Occupational Safety and Health Administration can be viewed here: https://www.osha.gov/video/respiratory-protection/fit-testing

A **user seal check** is different from a fit test and should be performed **every time** a respirator is put on. Advice on user seal checks is provided by the Canadian Centre for Occupational Health and Safety (CCOHS)[a] and can differ depending on the type of respirator. In general, the wearer identifies a good seal on inhalation by checking that there is slight collapse in the respirator and checks for leakage on exhalation by feeling around the edges or surface of the facepiece. Factors that can influence a poor fit or seal can include damage or deformation of the mask, and the presence of obstructions to fit.[112] Face size and shape can also influence fit,[111] and facial hair, especially full beards, can prevent a respirator from passing a fit test.[113] Studies on the success of user seal checks have found ***a significant number of users are not confirming fit correctly*** (near 50%).[111,114] Small leaks can result in a significant reduction in performance, therefore users should be trained on performing seal checks and re-confirming fit tests at intervals to ensure the size and shape of the respirator is still appropriate for the user.[111]

For other types of masks, a good fit that aligns to the contours of the face can reduce seepage of air around the edges of the mask. Masks with conical or tetrahedral shapes that fit closely with face contours perform better than loose-fitting masks.[13] Drewnick et al. found that for a range of materials, leaks covering just 0.5-2% of the sample area could reduce FE by more than 50%.[11] The ***use of modifications*** ranging from fasteners and a range of mask fitters or mask braces that improve the fit of a mask around the face have been found to significantly reduce leakage and improve FE.[22,69,115,116] Rothamer et al. found that in a simulated classroom aerosol-exposure scenario, the mask types tested (two cloth masks, a procedure mask and a surgical mask) had leakage rates around 50%. Filtration efficiency significantly improved with the addition of a mask fitter or mask brace, with the FE of a single-use procedure mask increasing from around 20% up to >90%, and a surgical mask (ASTM Level 2) improving from 44.6% to >91% for the range of aerosols tested.[115] A simulation by Brooks et al. using mannequin heads and simulated coughing assessed the effect of mask modifications such as knotting the ear loops of a procedure mask at the edges and tucking them in. They found that this modification blocked 77% of aerosols compared to 56.1% with the unmodified procedure mask, and an overall reduction in exposure of >95% when both the source and exposed mannequins wore a modified mask.[117] Clapp et al. also reported on the effect of a range of mask modifications for improving fit, with the best performance measured for nylon hosiery placed over a procedure mask, increasing FE to 80.2% compared to 38.5% for an unmodified procedure mask.[22] Similarly, Mueller et al. found an increase in FE for a standard medical mask from 54% when worn as designed to 86-90% with a nylon overlay.[69]

[a] CCOHS https://www.ccohs.ca/oshanswers/prevention/ppe/wearing.html?=undefined&wbdisable=true

Mask material

Mask material has been demonstrated to significantly influence FE as demonstrated in the laboratory studies discussed earlier. Materials with a higher thread count or multiple layers of different material help to increase FE, although there may be a trade-off with breathability.[75] For non-medical masks, PHAC recommends at least two layers of tightly woven fabric and a third layer of filter-type fabric, such as non-woven polypropylene (e.g., craft fabric, interfacing), or a disposable filter fitted into the pocket of the mask made from a paper kitchen towel, or a rinsed, dried baby wipe folded in half.[3,76]

New materials have been proposed by manufacturers to increase the functionality of masks by improving particle removal, breathability or electrostatic action, or incorporating materials to provide an antimicrobial effect by using films or coatings, or incorporating nanoparticles such as silver, gold, aluminum, zinc, copper, antimicrobial proteins, or graphene.[118-120] ***Nanomaterials*** have been shown to have antimicrobial properties on surfaces in other applications.[121] The antimicrobial effect arises through mechanisms such as metal ion generation, which can be toxic to cell walls and virus envelopes, or via the formation of reactive oxygen species that damage cell membranes. Several non-medical masks marketed as having antimicrobial properties are currently on the market with some claiming to instantly kill bacteria and viruses, including SARS-CoV-2, but there is limited published evidence on the efficacy of nanomaterials in masks to reduce transmission of the virus.

A key concern over the use of nanomaterials in face coverings is the potential exposure to nanoparticles via dermal contact or inhalation. The release of nanoparticles from a material could be influenced by how it is applied to materials (e.g., coating versus embedded nanoparticles), and how the material is released during use or handling (e.g., laundering). In April 2021, Health Canada issued an advisory for masks labelled as containing graphene or biomass graphene, and subsequently recalled masks and KN95 respirators containing biomass graphene based on the potential for wearers to inhale graphene particles, which can pose health risks.[122,123] Other nanoparticles may pose similar risks if exposure is found to be occurring via inhalation through a face mask but further research is needed to understand both the benefits and risks of incorporating nanomaterials in masks. Researchers at Sciensano (Belgian Institute for Health) are investigating the release of nanoparticles (e.g., nanosilver, titanium dioxide) in the AgMask project to identify whether nanoparticles are released and the potential exposure to mask wearers.[124] Research is ongoing to identify the effect of continuous mask use on the inhalation of microplastics. A laboratory study by Li et al. found that N95 respirators resulted in less microplastic inhalation compared to background levels over a 720-hour test. For other mask types (i.e., surgical, cotton, fashion mask and non-woven mask), a slight increase in inhalation of fibre-like microplastics above background levels was detected after four hours.[125]

Double masks

The proposed benefits of double masking include improved fit by helping to close gaps and reduce leakage around the side of the mask, and increased FE by adding more layers of material, which in theory block more particles from the external environment from entering the breathing zone of the wearer.[27,126] Guidance on double masking to improve fit and filtration is provided by the US CDC, suggesting the use of a procedure mask beneath a cloth mask.[127]

A review by Alberta Health Services (AHS) did not find any clinical studies that evaluated the effectiveness of double masking for reducing SARS-CoV-2 transmission; however, laboratory experiments have evaluated the impact of double masking on FE.[117,128] The simulation by Brooks et al. using mannequin heads and simulated coughing, which assessed mask modifications, also tested the effect of double masking. They found that using a double mask comprised of a 3-ply cloth mask over a 3-ply procedure mask blocked 85.4% of aerosols compared to 51.4% and 56.1% with a single cloth mask or procedure mask respectively.[117] An overall reduction in exposure of 94.5% was observed when both the source and exposed mannequins wore a double mask. This study did not assess the effect of double masking using two cloth masks.

Another small study of double masks using human volunteers found that, on average, FE increased 4-14% for procedure masks and about 14% for a double cotton mask compared to the equivalent single mask.[129] Notably, placing a procedure mask over a cloth mask did not appear to result in any improvement from wearing a single procedure mask; however, when a procedure mask was worn beneath a cloth mask, FE increased, with 66 to 81% FE being achieved for a procedure mask worn under a cloth mask.[129] The results from this study suggest that fit may be more important than material to improving mask performance. No studies were identified that provided evidence of harms from wearing a double mask.[128]

Face shields

There may be situations where face shields are considered for specific uses. Face shields allow for visibility of facial movements and expression, which may be beneficial for the hearing impaired. For HCWs or those caring for an infected person, the use of goggles or a face shield may be considered as complementary PPE (i.e., with a surgical mask) to prevent additional exposures due to splash and spray and some intake of particles that could occur due to loose-fitting masks.

There has been limited study of the effectiveness of face shields for reducing transmission of infectious respiratory diseases. There is some evidence that face shields may provide some additional protection when used as complementary PPE with masks.[130] The use of an integral visor with a surgical mask has been found to reduce leakage into the breathing zone around the nose.[16] Face shields can extend the usability of respirators or masks by reducing the potential for surface deposition or accidental contact with mask surfaces.[b] There is some evidence that infection with SARS-CoV-2 via the eyes is possible and face shields may provide additional protection of the wearer by preventing self-inoculation due to touching of the face or eyes.[131-135] The UK Scientific Advisory Group for Emergencies (SAGE) reported anecdotal evidence that the introduction to universal visor use (in addition to masks) in patient care in one NHS trust was associated with a significant decrease in nosocomial infection of SARS-CoV-2.[62]

Laboratory studies have assessed the ability of face shields to provide a physical barrier. A study using a coughing patient simulator and a breathing worker simulator found that face shields reduced surface contamination of a respirator by up to 97% for larger aerosols and 76% for smaller aerosols (median 8.5 and 3.5 µm diameter respectively). The same study found that the face shield provided a high reduction in initial inhalation exposure (96%) for larger aerosols, and a moderate reduction in exposure (68%) for smaller aerosols. After 1-30 minutes after the cough, the face shield only reduced aerosol inhalation by 23% as aerosols dispersed throughout the room and were able to flow around the sides of the shield.[136] The use of face shields as source control has not been widely assessed.[135] Ronen et al. demonstrated that using a face shield over a cough simulator blocked the release of droplets from the source and exposure to a nearby mannequin.[137] Verma et al. demonstrated that the initial forward projection of aerosols and droplets is blocked by a face shield, but these particles can move around the edges of the face shield relatively easily, and disperse over a larger area.[68] Li et al. found that when worn as the only face covering (e.g., no mask), cough generated aerosols were detected above background levels up to 1.8 m from the source (human volunteers), with the face shield alone providing only 4% reduction (with a large confidence interval of ± 23) compared to no face covering.[24] Together, this evidence suggests that while face shields block forward protection of droplets, leakage from seams and joints can occur, and upward, downward, sideways and backward leakage jets can result in the release of aerosols if not used in combination with a mask.[20,24,27,68,78] Where face shields are used as complementary to masks, they should be easy to don and doff, fit snugly with reduced areas for leakage, and provide full face coverage around the face and below the chin.[138]

Exhalation valves in masks

One limitation of respirators as source control is the presence of exhalation valves, which improve breathability of respirators while maintaining the protective effect for the wearer but may provide less protection of others from the wearer. Exhalation valves are also being incorporated into some cloth masks. Many health authorities, including the US CDC, advise against the use of valved respirators as source control, particularly in sterile environments, due to the potential for release of an unfiltered exhalation jet from the wearer.[139] This has been demonstrated in a visualization study of the exhalation jet from a valved respirator, which indicated significantly more leakage of

[b] Public Health Ontario. Recommended steps for donning and doffing of PPE: https://www.publichealthontario.ca/-/media/documents/rpap-recommeded-ppe-steps.pdf?la=en

aerosols compared to an un-valved respirator.[68] There is limited evidence available to assess whether the use of valved masks in community settings increases transmission risks compared to other non-medical face coverings.[140] A quantitative study by Fischer et al. (2020) found that a valved N95 respirator released more particles over time compared to an un-valved N95 and a surgical mask but performed similarly or better than some cloth masks.[67] A study comparing emission of aerosol-size particles during breathing, talking and coughing found that in comparison to a surgical mask and an un-valved KN95 respirator, a valved N95 mask demonstrated similar performance, and all were better than homemade paper and cloth masks for blocking aerosol transmission, albeit the valved mask was tested on a smaller number of study participants.[56]

Length of use

The longer a mask is used, the greater the risk for infectious particles to become deposited on the surface.[141] Surgical masks or respirators (e.g., N95s) that become wet, damaged, torn, visibly dirty, or contaminated following close contact with an infected person will not provide adequate protection. A study of mask use by HCWs found that very low levels of surface contamination with respiratory viruses was observed for masks used less than six hours; however, a greater virus positivity was found beyond six hours of use, and for HCWs who examined more than 25 patients.[141] The potential presence of viruses on the outer surface suggests a need for caution during doffing practices by avoiding contact with the mask surface (Box 2), and preventing the resuspension of deposited aerosols.[142] In healthcare settings, continuous mask use (avoiding frequent donning and doffing) was identified to be important to maintaining a protective effect against respiratory viruses.[51] Frequent donning and doffing of the same mask can increase the risk of surface contamination on both the inside and the outside of masks and continuous use of respirators may reduce the potential for contamination as compared to frequent donning and doffing of the same mask.[143]

Box 2: Tips for safe mask doffing

1. Assume that the surface of a mask or respirator is contaminated and take care not to touch the surface when removing the mask.
2. Remove the loops around the ear, or for ties or straps that go around the back of the head, untie or remove the bottom ties first followed by the top ties, without touching the mask surface. Pull the mask away from the face.
3. For disposable masks, hold by the straps or ties and place directly in a garbage bin with a lid.
4. For reusable masks that may be disinfected (respirators) or laundered (cloth masks), hold the ties and place into a suitable receptacle such as a sealable bin or disposable plastic bag until the mask can be placed in the laundry or disinfection chamber.
5. Wash hands with soap and water or sanitize after discarding the mask.

Discomfort can lead to frequent adjustments of masks, and has been observed to be a primary reasons for non-adherence to mask use.[110] Discomfort can be linked to air resistance and build-up of water vapour and heat within the breathing zone of the mask, with cotton and procedure/surgical masks performing better than some respirators for comfort.[110] Mask comfort and length of use go hand in hand, as discomfort and poor fit may lead to frequent adjustments and inability to comply with mask use over a longer duration.

Early in the COVID-19 pandemic, concern was raised that adoption of universal masking in the community could reduce adherence to other public health measures such as distancing and handwashing. Doung-ngern et al. found that mask wearers in Thailand were more likely to observe distancing and handwashing measures compared to non-mask wearers, but were also more likely to have physical contact and long duration of contact (e.g., > 60 minutes) compared to non-mask wearers.[33] Communication on mask-wearing by public health authorities should emphasize the importance of continued adherence to other protective behaviours, along with mask-wearing. Masks should not be used to avoid self-isolation requirements by those who are symptomatic or may have been exposed to COVID-19. PHAC recommends washing hands or using hand sanitizer after adjusting, donning or doffing a mask; not hanging it from a lanyard or wearing if under your chin; storing in a clean paper or cloth bag until needed again; changing if damp or dirty; and discarding disposable masks and filters in the garbage.

Decontamination and reuse of masks

Masks can become contaminated by the user and the external environment. For cloth masks, laundering in a hot wash and thoroughly drying is recommended by PHAC, but any damage, deterioration or reduced fit will reduce the protective function of cloth masks. Surgical masks are considered disposable and not recommended for decontamination and reuse. Laundering or disinfection processes can potentially damage the protective layers of the surgical masks, reducing their effectiveness.

Several decontamination methods have been considered for the purpose of providing additional supplies of respirators when there is high demand and to reduce waste. The key criteria for effective decontamination methods are stated as follows: the ability to remove the viral threat; maintaining the integrity of mask elements; and being harmless to the user.[4,144,145] Decontamination methods include autoclaving; microwave steam sterilization; washing in soap and water; dry heat treatment; treatment with isopropyl alcohol, bleach, hydrogen peroxide vapour, or gamma irradiation; ozone decontamination; UV germicidal irradiation (UVGI) and ethylene oxide treatment.[144-148] Promising results have been observed for hydrogen peroxide vapour and UVGI; however, any reuse of decontaminated respirators should include steps to inspect respirators for deterioration and damage and to include user seal testing prior to reuse.[144,145,147,149]

Expired, counterfeit and recalled masks

Surgical masks and respirators that have been certified by organizations such as NIOSH or the FDA have an expiry date, after which they are no longer considered to be certified. In times of high demand, expired masks may be considered for use following a visual inspection for any damage or degradation of the mask components, including the straps. For expired N95 respirators, the ability to form an effective face seal should also be confirmed by a fit test and user seal check.[150]

Health Canada has issued recalls for several mask and respirator products including some surgical masks and KN95 and N95 respirators. Reasons for recalls include improper or misleading packaging such as labelling as "N95" respirators without NIOSH certification, or testing by Health Canada indicating that the product does not meet the specification stated. These recalls are intended to remove products that may not provide consistent and adequate respiratory protection or may present health risks such as masks containing graphene or biomass graphene mentioned previously. Further advice from Health Canada on fraudulent and unauthorized N95 respirators is provided here. The US CDC also keeps up-to-date lists of counterfeit respirators or devices that misrepresent NIOSH-approval.

Mask use for children

The WHO has published advice on the use of masks for children.[151] The evidence on the benefits or harms of children wearing masks to limit transmission of SARS-CoV-2 is limited,[152] although evidence from other respiratory diseases suggests mask-wearing may be more effective for older children (e.g., nine years and above) than younger children. This may be due to multiple factors, such as the mechanisms of disease transmission, and the acceptability of mask-wearing and level of compliance among children of different ages. The WHO recommends that masks are not worn by children aged up to five years for source control, but where a lower cut-off age is used, adult supervision is recommended. For older children up to 11 years, a risk-based approach to decision making is recommended based on the level of community transmission, socio-cultural factors, impacts on learning and development, and the settings and scenarios in which mask-wearing may be more appropriate. Older children 12 and above are recommended to follow guidance on masks for adults. The WHO also recommends that children with cognitive or respiratory impairments should not be required to wear masks, and alternatives for children with developmental disorders and disabilities should be considered.

PHAC recommends that children under two should not wear masks, and between two and five should be able to wear one if supervised. Children older than five can wear a mask in situations or settings where they are recommended but their ability to properly use a mask may be impacted by age, maturity, and physical and cognitive ability.

Mask use for persons with cognitive difficulties or physical disabilities

There are some people who may not be able to wear masks such as persons with cognitive difficulties or physical disabilities who are unable to safely don or doff a mask without help. For persons who are unable to wear a mask safely, those providing care and support should be aware of appropriate infection prevention and control measures and take precautions to minimize risk of transmission to the person under care, and to others.[153]

Persons with hearing impairments may find communication with others difficult where their communication partners are wearing masks. Mask-wearing may also provide discomfort to those with breathing difficulties. Where safe to do so, wearing of alternative face coverings such as face shields or clear masks may be considered, recognizing the limitations of these alternatives and importance of other measures such as physical distancing and hand hygiene.[153,154]

Mask-wearing, variants and vaccines

The emergence of variants of concern (VOC) throughout late 2020 and early 2021 highlight the potential for viral mutations to lead to more transmissible variants, or mutations that are more difficult to control with current vaccines. This has raised questions over whether new or amended recommendations for mask-wearing should be considered. A report by the UK SAGE group in reference to mask use and VOC found that there is no evidence that the mode of transmission has changed, but the increased transmissibility of VOC likely means that a lower dose and shorter exposure may lead to transmission, so risks from all transmission routes are heightened.[155] Recommendations include consistent application of existing mitigation measures, including hand hygiene and correct and consistent use of good-quality face coverings. A jurisdictional scan of mask-wearing recommendations across 14 countries by Public Health Ontario identified that three countries (Austria, France, and Germany) had upgraded their recommendations for mask-wearing in the community from non-medical face coverings to a medical mask (certified surgical mask or respirator). Other countries maintained their recommendations for face coverings in public places.

As vaccinations increase in other parts of the world, masking mandates are also being lifted in countries with high levels of community vaccination such as Israel, the UK, and the US. The lifting of masking requirements has been gradual, starting with outdoor public spaces, where they apply, and gradually moving to more locations. The US CDC indicated in early May 2021 that mask-wearing requirements would be relaxed for fully vaccinated individuals in any setting, outdoors or indoors, except where required by other federal, state, local, tribal or territorial laws, rules and regulations.[156] This includes maintaining mask-wearing on planes and public transportation. At the time of writing, Canada-wide advice on relaxation of masking recommendations post-vaccination had not been published.

Whether or not mask mandates are lifted across all areas of society, many individuals may choose to continue to wear masks when in crowded public spaces, or when meeting with large groups, or on public transit. With uncertainty over the efficacy of current vaccines against future VOC, a gradual approach to lifting masking recommendations may be needed. Businesses or other public facilities may choose to keep up with general mask recommendations for protection of staff and patrons. An increased awareness of routes of transmission of respiratory viruses may also encourage some people to adopt seasonal use of masks in public to reduce the risk of colds or flu or other emerging illnesses.

Conclusions

Masks vary widely in their design, construction, and the level of protection against respiratory viruses that they can provide to the wearer and to others as source control. The use of medical masks including approved respirators (e.g., N95s and similar) and surgical masks can reduce the transmission of respiratory infection in healthcare settings. The use of non-medical masks by the public may also reduce the risk of transmission of respiratory infection in community settings, especially when used by both infected and susceptible persons, but masking does not eliminate the risk of transmission entirely. Key messages arising from the evidence presented in this updated document include the following:

Key messages

- Most face coverings are found to provide some reduction in the release of and exposure to larger droplets.
- Performance against smaller aerosols varies widely, with certified respirators providing the best performance. A very well-fitted surgical mask (e.g., with modifications to improve fit) can also provide good protection against aerosol spread.
- Across the wide range of material types, layers and aerosol sizes tested, cloth masks are most efficient for blocking large particles (droplets), but performance against smaller aerosols varies and can be dependent on material type, construction and fit.
- The most effective cloth masks are those that provide a good fit around the nose, sides, and chin, and are made of materials that provide a high level of particle filtration, while maintaining breathability.
- Systematic reviews and modelling studies have indicated that mask-wearing has reduced the number of cases and growth rate of COVID-19 infections where there was early uptake, widespread adherence, and when used in combination with other non-pharmaceutical interventions such as hand hygiene and physical distancing.
- Users of medical masks and respirators should be aware of appropriate fit testing and safe donning and doffing procedures, including a routine update of respirator fit testing (e.g., annually) and seal-check procedures.
- Counterfeit and recalled products may provide inadequate respiratory protection. Users should consult trusted government sources prior to procuring products.
- Measures to improve fit including some mask modifications and double masking have been shown to improve filtration efficiency but may reduce breathability and comfort.

- Exhalation valves reduce the effectiveness of masks as source control and should not be used in sterile environments.
- Face shields should be considered as complementary to wearing of masks, but not as an alternative except in circumstances where mask-wearing is not possible.
- Special consideration should be given to children or to persons with cognitive difficulties or physical disabilities when considering appropriate mask use.

Several knowledge gaps still exist. These include the need to better understand the effect of mask-wearing on reducing community transmission of SARS-CoV-2, including how mask-wearing influences the exposure dose and the relationship between dose and severity of disease. Further study is also needed on how adherence to mask-wearing (e.g., how masks are worn, where they are worn, and for how long) and other complementary public health measures influence the observed effects. Further study on new materials, including nanomaterials, are needed to explore the effect of antimicrobial properties on reducing transmission, and to understand and mitigate any potential human health effects from inhalation or dermal exposures.

The information provided in this document is based on current understanding and interpretation of the scientific evidence concerning the effectiveness of mask-wearing. As new evidence emerges, this document may be updated.

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References

1. World Health Organization. Coronavirus disease (COVID-19) advice for the public: when and how to use masks. Geneva, Switzerland: WHO; 2020 [updated 2020 Dec 1]; Available from: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public/when-and-how-to-use-masks.
2. Public Health Agency of Canada. Coronavirus disease (COVID-19): prevention and risks. Ottawa, ON: PHAC; 2021 [updated Apr 20]; Available from: https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/prevention-risks.html.
3. Public Health Agency of Canada. Non-medical masks: about. Ottawa, ON: PHAC; 2021 Feb 11. Available from: https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/prevention-risks/about-non-medical-masks-face-coverings.html.
4. Institute of Medicine. Reusability of facemasks during an influenza pandemic: facing the flu. Washington, DC: The National Academies Press; 2006. Available from: https://www.nap.edu/catalog/11637/reusability-of-facemasks-during-an-influenza-pandemic-facing-the-flu.
5. Li Y. The secret behind the mask. Indoor Air. 2011 Apr;21(2):89-91. Available from: https://doi.org/10.1111/j.1600-0668.2011.00711.x.
6. Rengasamy S, Eimer B, Shaffer RE. Simple respiratory protection—evaluation of the filtration performance of cloth masks and common fabric materials against 20–1000 nm size particles. Ann Occup Hyg. 2010;54(7):789-98. Available from: https://doi.org/10.1093/annhyg/meq044.
7. 3M. Comparison of FFP2, KN95, and N95 and other filtering facepiece respirator classes. St. Paul, MN: 3M; 2020 May. Available from: https://multimedia.3m.com/mws/media/1791500O/comparison-ffp2-kn95-n95-filtering-facepiece-respirator-classes-tb.pdf.
8. Public Health Agency of Canada. Non-medical masks and face coverings: how to put on, remove and clean. Ottawa, ON: PHAC; 2021 Feb 11. Available from: https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/prevention-risks/how-put-remove-clean-non-medical-masks-face-coverings.html.
9. Lee SA, Hwang DC, Li HY, Tsai CF, Chen CW, Chen JK. Particle size-selective assessment of protection of European standard FFP respirators and surgical masks against particles-tested with human subjects. J Healthc Eng. 2016:8572493. Available from: https://doi.org/10.1155/2016/8572493.
10. Davies A, Thompson K-A, Giri K, Kafatos G, Walker J, Bennett A. Testing the efficacy of homemade masks: would they protect in an influenza pandemic? Disaster Med Public Health Prep. 2013;7(4):413-8. Available from: https://dx.doi.org/10.1017%2Fdmp.2013.43.
11. Drewnick F, Pikmann J, Fachinger F, Moormann L, Sprang F, Borrmann S. Aerosol filtration efficiency of household materials for homemade face masks: influence of material properties, particle size, particle electrical charge, face velocity, and leaks. Aerosol Sci Technol. 2021;55(1):63-79. Available from: https://doi.org/10.1080/02786826.2020.1817846.
12. Lindsley WG, Blachere FM, Beezhold DH, Law BF, Derk RC, Hettick JM, et al. A comparison of performance metrics for cloth face masks as source control devices for simulated cough and exhalation aerosols. medRxiv. 2021 Feb 19. Available from: https://doi.org/10.1101/2021.02.16.21251850.
13. Shakya KM, Noyes A, Kallin R, Peltier RE. Evaluating the efficacy of cloth facemasks in reducing particulate matter exposure. J Expo Sci Environ Epidemiol. 2017 May 1;27(3):352-7. Available from: https://doi.org/10.1038/jes.2016.42.
14. Jung H, Kim JK, Lee S, Lee J, Kim J, Tsai P, et al. Comparison of filtration efficiency and pressure drop in anti-yellow sand masks, quarantine masks, medical masks, general masks, and handkerchiefs. Aerosol Air Qual Res. 2014;14(3):991-1002. Available from: https://doi.org/10.4209/aaqr.2013.06.0201.
15. Leung NHL, Chu DKW, Shiu EYC, Chan K-H, McDevitt JJ, Hau BJP, et al. Respiratory virus shedding in exhaled breath and efficacy of face masks. Nat Med. 2020 Apr 3. Available from: https://doi.org/10.1038/s41591-020-0843-2.

16. Makison Booth C, Clayton M, Crook B, Gawn JM. Effectiveness of surgical masks against influenza bioaerosols. J Hosp Infect. 2013;84(1):22-6. Available from: https://doi.org/10.1016/j.jhin.2013.02.007.
17. Milton DK, Fabian MP, Cowling BJ, Grantham ML, McDevitt JJ. Influenza virus aerosols in human exhaled breath: particle size, culturability, and effect of surgical masks. PLoS Pathog. 2013;9(3):e1003205. Available from: https://doi.org/10.1371/journal.ppat.1003205.
18. Lindsley WG, Beezhold DH, Coyle J, Derk RC, Blachere FM, Boots T, et al. Efficacy of universal masking for source control and personal protection from simulated cough and exhaled aerosols in a room. medRxiv. 2021 Apr 25. Available from: https://doi.org/10.1101/2021.04.21.21255880.
19. Guha S, Herman A, Carr IA, Porter D, Natu R, Berman S, et al. Comprehensive characterization of protective face coverings made from household fabrics. PLOS ONE. 2021;16(1):e0244626. Available from: https://doi.org/10.1371/journal.pone.0244626.
20. Viola I, Peterson B, Pisetta G, Pavar G, Akhtar H, Menoloascina F, et al. Face coverings, aerosol dispersion and mitigation of virus transmission risk. IEEE Open J Eng Med Biol. 2021;2(26-35). Available from: https://doi.org/10.1109/OJEMB.2021.3053215.
21. Sickbert-Bennett EE, Samet JM, Clapp PW, Chen H, Berntsen J, Zeman KL, et al. Filtration efficiency of hospital face mask alternatives available for use during the COVID-19 pandemic. JAMA Intern Med. 2020;180(12):1607-12. Available from: https://doi.org/10.1001/jamainternmed.2020.4221.
22. Clapp PW, Sickbert-Bennett EE, Samet JM, Berntsen J, Zeman KL, Anderson DJ, et al. Evaluation of cloth masks and modified procedure masks as personal protective equipment for the public during the COVID-19 pandemic. JAMA Intern Med. 2020. Available from: https://doi.org/10.1001/jamainternmed.2020.8168.
23. Hao W, Parasch A, Williams S, Li J, Ma H, Burken J, et al. Filtration performances of non-medical materials as candidates for manufacturing facemasks and respirators. Int J Hyg Environ Health. 2020 Aug;229:113582. Available from: https://doi.org/10.1016/j.ijheh.2020.113582.
24. Li L, Niu M, Zhu Y. Assessing the effectiveness of using various face coverings to mitigate the transport of airborne particles produced by coughing indoors. Aerosol Sci Technol. 2020 Dec 4:1-12. Available from: https://doi.org/10.1080/02786826.2020.1846679.
25. Li I, Fan J, Lai A, Lo C. Home-made masks with filtration efficiency for nano-aerosols for community mitigation of COVID-19 pandemic. Public Health. 2020;188:42-50. Available from: https://doi.org/10.1016/j.puhe.2020.08.018.
26. Kolewe EL, Stillman Z, Woodward IR, Fromen CA. Check the gap: facemask performance and exhaled aerosol distributions around the wearer. PLOS ONE. 2020;15(12):e0243885. Available from: https://doi.org/10.1371/journal.pone.0243885.
27. Pan J, Harb C, Leng W, Marr LC. Inward and outward effectiveness of cloth masks, a surgical mask, and a face shield. Aerosol Sci Technol. 2020;55(6):718-33. Available from: https://doi.org/10.1080/02786826.2021.1890687.
28. Wang X, Pan Z, Cheng Z. Association between 2019-nCoV transmission and N95 respirator use. J Hosp Infect. 2020;105(1):104-5. Available from: https://doi.org/10.1016/j.jhin.2020.02.021.
29. Wang X, Ferro EG, Zhou G, Hashimoto D, Bhatt DL. Association between universal masking in a health care system and SARS-CoV-2 positivity among health care workers. JAMA. 2020;324(7):703-4. Available from: https://doi.org/10.1001/jama.2020.12897.
30. Kori N, Periyasamy P, Ng BH, Satariah A, Zainol R. Aerosolised COVID-19 transmission risk: surgical or N95 masks? Infect Control Hosp Epidemiol. 2020 Sep 15;1-2. Available from: https://doi.org/10.1017/ice.2020.465.
31. Ng K, Poon BH, Kiat Puar TH, Shan Quah JL, Loh WJ, Wong YJ, et al. Covid-19 and the risk to health care workers: a case report. Ann Intern Med. 2020. Available from: https://doi.org/10.7326/L20-0175.
32. Wong SCY, Kwong RTS, Wu TC, Chan JWM, Chu MY, Lee SY, et al. Risk of nosocomial transmission of coronavirus disease 2019: an experience in a general ward setting in Hong Kong. J Hosp Infect. 2020;105(2):119-27. Available from: https://doi.org/10.1016/j.jhin.2020.03.036.

33. Doung-ngern P, Suphanchaimat R, Panjangampatthana A, Janekrongtham C, Ruampoom D, Daochaeng N, et al. Case-control study of use of personal protective measures and risk for severe acute respiratory syndrome coronavirus 2 infection, Thailand. Emerg Infect Dis. 2020;26(11):2607-16. Available from: https://doi.org/10.3201/eid2611.203003.
34. Cheng VCC, Wong SC, Chuang VWM, So SYC, Chen JHK, Sridhar S, et al. The role of community-wide wearing of face mask for control of coronavirus disease 2019 (COVID-19) epidemic due to SARS-CoV-2. J Infect. 2020 Apr 23;81(1):107-14. Available from: https://dx.doi.org/10.1016%2Fj.jinf.2020.04.024.
35. Lyu W, Wehby G. Community use of face masks and COVID-19: evidence from a natural experiment of state mandates in the US. Health Aff. 2020;39(8):1419-25. Available from: https://doi.org/10.1377/hlthaff.2020.00818.
36. Worden L, Wannier R, Blumberg S, Ge AY, Rutherford GW, Porco TC. Estimation of effects of contact tracing and mask adoption on COVID-19 transmission in San Francisco: a modeling study. medRxiv. 2020 Jun 11. Available from: https://doi.org/10.1101/2020.06.09.20125831.
37. Xu H, Gan Y, Zheng D, Wu B, Zhu X, Xu C, et al. Relationship between COVID-19 infection and risk perception, knowledge, attitude as well as four non-pharmaceutical interventions during the late period of the COVID-19 epidemic in China: online cross-sectional survey of 8158 adults. J Med Internet Res. 2020;22(11):e21372. Available from: https://doi.org/10.2196/21372.
38. Guy GJ, Lee F, Sunshine G, McCord R, Howard-Williams M, Kompaniyets L, et al. Association of state-issued mask mandates and allowing on-premises restaurant dining with county-level COVID-19 case and death growth rates — United States, March 1–December 31, 2020. Morb Mortal Wkly Rep. 2021;70:350-4. Available from: http://dx.doi.org/10.15585/mmwr.mm7010e3.
39. Aiello AE, Murray GF, Perez V, Coulborn RM, Davis BM, Uddin M, et al. Mask use, hand hygiene, and seasonal influenza-like illness among young adults: a randomized intervention trial. J Infect Dis. 2010;201(4):491-8. Available from: https://doi.org/10.1086/650396.
40. Canini L, Andréoletti L, Ferrari P, D'Angelo R, Blanchon T, Lemaitre M, et al. Surgical mask to prevent influenza transmission in households: a cluster randomized trial. PLOS ONE. 2010;5(11):e13998. Available from: https://doi.org/10.1371/journal.pone.0013998.
41. Cowling BJ, Chan K-H, Fang VJ, Cheng CKY, Fung ROP, Wai W, et al. Facemasks and hand hygiene to prevent influenza transmission in households: a cluster randomized trial. Ann Intern Med. 2009;151(7):437-46. Available from: https://doi.org/10.7326/0003-4819-151-7-200910060-00142.
42. MacIntyre CR, Seale H, Dung TC, Hien NT, Nga PT, Chughtai AA, et al. A cluster randomised trial of cloth masks compared with medical masks in healthcare workers. BMJ Open. 2015;5(4):e006577. Available from: http://dx.doi.org/10.1136/bmjopen-2016-012330.
43. MacIntyre CR, Wang Q, Cauchemez S, Seale H, Dwyer DE, Yang P, et al. A cluster randomized clinical trial comparing fit-tested and non-fit-tested N95 respirators to medical masks to prevent respiratory virus infection in health care workers. Influenza Other Respir Viruses. 2011 May 1;5(3):170-9. Available from: https://doi.org/10.1111/j.1750-2659.2011.00198.x.
44. MacIntyre CR, Wang Q, Seale H, Yang P, Shi W, Gao Z, et al. A randomized clinical trial of three options for N95 respirators and medical masks in health workers. Am J Respir Crit Care Med. 2013 May 1;187(9):960-6. Available from: https://doi.org/10.1164/rccm.201207-1164OC.
45. MacIntyre CR, Zhang Y, Chughtai AA, Seale H, Zhang D, Chu Y, et al. Cluster randomised controlled trial to examine medical mask use as source control for people with respiratory illness. BMJ Open. 2016;6(12):e012330. Available from: https://doi.org/10.1136/bmjopen-2016-012330.
46. Suess T, Remschmidt C, Schink SB, Schweiger B, Nitsche A, Schroeder K, et al. The role of facemasks and hand hygiene in the prevention of influenza transmission in households: results from a cluster randomised trial; Berlin, Germany, 2009-2011. BMC Infect Dis. 2012;12(1):26. Available from: https://doi.org/10.1186/1471-2334-12-26.
47. Radonovich LJ, Jr., Simberkoff MS, Bessesen MT, Brown AC, Cummings DAT, Gaydos CA, et al. N95 respirators vs medical masks for preventing influenza among health care personnel: a randomized clinical trial. JAMA. 2019 Sep 3;322(9):824-33. Available from: https://doi.org/10.1001/jama.2019.11645.

48. Chu DK, Akl EA, Duda S, Solo K, Yaacoub S, Schünemann HJ, et al. Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis. The Lancet. 2020;395(10242):1973-87. Available from: https://doi.org/10.1016/S0140-6736(20)31142-9.
49. Offeddu V, Yung CF, Low MSF, Tam CC. Effectiveness of masks and respirators against respiratory infections in healthcare workers: a systematic review and meta-analysis. Clin Infect Dis. 2017;65(11):1934-42. Available from: https://doi.org/10.1093/cid/cix681.
50. Bartoszko JJ, Farooqi MAM, Alhazzani W, Loeb M. Medical masks vs N95 respirators for preventing COVID-19 in healthcare workers: a systematic review and meta-analysis of randomized trials. Influenza Other Respi Viruses. 2020 Jul;14(4):365-73. Available from: https://doi.org/10.1111/irv.12745.
51. MacIntyre CR, Chughtai AA. A rapid systematic review of the efficacy of face masks and respirators against coronaviruses and other respiratory transmissible viruses for the community, healthcare workers and sick patients. Int J Nurs Stud. 2020;108:103629. Available from: https://dx.doi.org/10.1016%2Fj.ijnurstu.2020.103629.
52. Liang M, Gao L, Cheng C, Zhou Q, Uy JP, Heiner K, et al. Efficacy of face mask in preventing respiratory virus transmission: a systematic review and meta-analysis. Travel Med Infect Dis. 2020:101751. Available from: https://doi.org/10.1016/j.tmaid.2020.101751.
53. Chaabna K, Doraiswamy S, Mamtani R, Cheema S. Facemask use in community settings to prevent respiratory infection transmission: a rapid review and meta-analysis. Int J Infect Dis. 2021;104:198-206. Available from: https://doi.org/10.1016/j.ijid.2020.09.1434.
54. Abboah-Offei M, Salifu Y, Adewale B, Bayuo J, Ofosu-Poku R, Opare-Lokko EBA. A rapid review of the use of face mask in preventing the spread of COVID-19. Int J Adv Nurs Stud. 2021;3:100013. Available from: https://doi.org/10.1016/j.ijnsa.2020.100013.
55. van der Sande M, Teunis P, Sabel R. Professional and home-made face masks reduce exposure to respiratory infections among the general population. PLOS ONE. 2008;3(7):e2618. Available from: https://doi.org/10.1371/journal.pone.0002618.
56. Asadi S, Cappa CD, Barreda S, Wexler AS, Bouvier NM, Ristenpart WD. Efficacy of masks and face coverings in controlling outward aerosol particle emission from expiratory activities. Sci Rep. 2020;10(1):15665. Available from: https://doi.org/10.1038/s41598-020-72798-7.
57. Balazy A, Toivola M, Adhikari A, Sivasubramani SK, Reponen T, Grinshpun SA. Do N95 respirators provide 95% protection level against airborne viruses, and how adequate are surgical masks? Am J Infect Control. 2006;34(2):51-7. Available from: https://doi.org/10.1016/j.ajic.2005.08.018.
58. Bischoff WE, Reid T, Russell GB, Peters TR. Transocular entry of seasonal influenza-attenuated virus aerosols and the efficacy of N95 respirators, surgical masks, and eye protection in humans. J Infect Dis. 2011 Jul 15;204(2):193-9. Available from: https://doi.org/10.1093/infdis/jir238.
59. Hui DS, Chow BK, Chu L, Ng SS, Lee N, Gin T, et al. Exhaled air dispersion during coughing with and without wearing a surgical or N95 mask. PloS one. 2012;7(12):e50845-e. Available from: https://doi.org/10.1371/journal.pone.0050845.
60. Inglesby TV. Public health measures and the reproduction number of SARS-CoV-2. JAMA. 2020;323(21):2186-7. Available from: https://doi.org/10.1001/jama.2020.7878.
61. Loeb M, Dafoe N, Mahony J, John M, Sarabia A, Glavin V, et al. Surgical mask vs N95 respirator for preventing influenza among health care workers: a randomized trial. JAMA. 2009;302(17):1865-71. Available from: https://doi.org/10.1001/jama.2009.1466.
62. Scientific Advisory Group for Emergencies. Masks for healthcare workers to mitigate airborne transmission of SARS-CoV-2. London, UK: UK Government; 2021 Apr 23. Available from: https://www.gov.uk/government/publications/emg-masks-for-healthcare-workers-to-mitigate-airborne-transmission-of-sars-cov-2-25-march-2021.
63. Jefferson T, Del Mar CB, Dooley L, Ferroni E, Al-Ansary LA, Bawazeer GA, et al. Physical interventions to interrupt or reduce the spread of respiratory viruses. Cochrane Database Syst Rev. 2011(7). Available from: https://doi.org//10.1002/14651858.CD006207.pub4.

64. Long Y, Hu T, Liu L, Chen R, Guo Q, Yang L, et al. Effectiveness of N95 respirators versus surgical masks against influenza: a systematic review and meta-analysis. J Evid Based Med. 2020;13(2):93-101. Available from: https://doi.org/10.1111/jebm.12381.
65. Jefferson T, Del Mar C, Dooley L, Ferroni E, Al-Ansary L, Bawazeer G. Physical interventions to interrupt or reduce the spread of respiratory viruses. Cochrane Database Syst Rev. 2020;11. Available from: https://doi.org//10.1002/14651858.CD006207.pub5.
66. Chou R, Dana T, Jungbauer R, Weeks C. Update alert 5: masks for prevention of respiratory virus infections, including SARS-CoV-2, in health care and community settings. Ann Intern Med. 2021 Mar 9. Available from: https://doi.org/10.7326/L21-0116.
67. Fischer EP, Fischer MC, Grass D, Henrion I, Warren WS, Westman E. Low-cost measurement of face mask efficacy for filtering expelled droplets during speech. Sci Adv. 2020 Sep;6(36). Available from: https://doi.org/10.1126/sciadv.abd3083.
68. Verma S, Dhanak M, Frankenfield J. Visualizing droplet dispersal for face shields and masks with exhalation valves. Phys Fluids (1994). 2020 Sep 1;32(9):091701. Available from: https://doi.org/10.1063/5.0022968.
69. Mueller AV, Eden MJ, Oakes JJ, Bellini C, Fernandez LA. Quantitative method for comparative assessment of particle removal efficiency of fabric masks as alternatives to standard surgical masks for PPE. Matter. 2020;3(3):P950-62. Available from: https://doi.org/10.1016/j.matt.2020.07.006.
70. Hao W, Xu G, Wang Y. Factors influencing the filtration performance of homemade face masks. J Occup Environ Hyg. 2021;18(3):128-38. Available from: https://doi.org/10.1080/15459624.2020.1868482.
71. Sokol KA, De la Vega-Diaz I, Edmondson-Martin K, Kim S, Tindle S, Wallach F, et al. Masks for prevention of respiratory viruses on the BMT unit: results of a quality initiative. Transpl Infect Dis. 2016;18(6):965-7. Available from: https://doi.org/10.1111/tid.12608.
72. Cowling BJ, Fung RO, Cheng CK, Fang VJ, Chan KH, Seto WH, et al. Preliminary findings of a randomized trial of non-pharmaceutical interventions to prevent influenza transmission in households. PLoS One. 2008 May 7;3(5):e2101. Available from: https://doi.org/10.1371/journal.pone.0002101.
73. MacIntyre CR, Cauchemez S, Dwyer DE, Seale H, Cheung P, Browne G, et al. Face mask use and control of respiratory virus transmission in households. Emerg Infect Dis. 2009;15(2):233-41. Available from: https://doi.org/10.3201/eid1502.081167.
74. Maurer L, Peris D, Kerl J, Guenther F, Koehler D, Dellweg D. Community masks during the SARS-CoV-2 pandemic: filtration efficacy and air resistance. J Aerosol Med Pulm Drug Deliv. 2021 Feb:11-9. Available from: http://doi.org/10.1089/jamp.2020.1635.
75. Rogak SN, Sipkens TA, Guan M, Nikookar H, Vargas Figueroa D, Wang J. Properties of materials considered for improvised masks. Aerosol Sci Technol. 2021;55(4):398-413. Available from: https://doi.org/10.1080/02786826.2020.1855321.
76. Public Health Agency of Canada. Non-medical masks: sew and no-sew instructions. Ottawa, ON: PHAC; 2021 Feb 10. Available from: https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/prevention-risks/sew-no-sew-instructions-non-medical-masks-face-coverings.html.
77. Lustig SR, Biswakarma JJH, Rana D, Tilford SH, Hu W, Su M, et al. Effectiveness of common fabrics to block aqueous aerosols of virus-like nanoparticles. ACS Nano. 2020 Jun 23;14(6):7651-8. Available from: https://doi.org/10.1021/acsnano.0c03972.
78. Stephenson TB, Cumberland C, Kibble G, Church C, Nogueira-Prewitt S, MacNamara S, et al. Evaluation of facial protection against close-contact droplet transmission. medRxiv. 2021 Feb 12. Available from: https://doi.org/10.1101/2021.02.09.21251443.
79. Ueki H, Furusawa Y, Iwatsuki-Horimoto K, Imai M, Kabata H, Nishimura H, et al. Effectiveness of face masks in preventing airborne transmission of SARS-CoV-2. mSphere. 2020;5(5):e00637-20. Available from: https://doi.org/10.1128/mSphere.00637-20.
80. Brooks JT, Butler JC. Effectiveness of mask wearing to control community spread of SARS-CoV-2. JAMA. 2021;325(10):998-9. Available from: https://doi.org/10.1001/jama.2021.1505.

81. Wang Y, Tian H, Zhang L, Zhang M, Guo D, Wu W, et al. Reduction of secondary transmission of SARS-CoV-2 in households by face mask use, disinfection and social distancing: a cohort study in Beijing, China. BMJ Glob Health. 2020;5(5):e002794. Available from: https://doi.org/10.1136/bmjgh-2020-002794.
82. Herstein J, Degarege A, Stover D, Austin C, Schwedhelm M, Lawler J, et al. Characteristics of SARS-CoV-2 transmission among meat processing workers in Nebraska, USA, and effectiveness of risk mitigation measures. Emerg Infect Dis. 2021;27(4):1032-8. Available from: https://dx.doi.org/10.3201/eid2704.204800.
83. Hong L-X, Lin A, He Z-B, Zhao H-H, Zhang J-G, Zhang C, et al. Mask wearing in pre-symptomatic patients prevents SARS-CoV-2 transmission: an epidemiological analysis. Travel Med Infect Dis. 2020;36:101803-. Available from: https://doi.org/10.1016/j.tmaid.2020.101803.
84. Hendrix M, Walde C, Findley K, Trotman R. Absence of apparent transmission of SARS-CoV-2 from two stylists after exposure at a hair salon with a universal face covering policy — Springfield, Missouri, May 2020. MMWR. 2020;69(28):930-2. Available from: http://dx.doi.org/10.15585/mmwr.mm6928e2external.
85. Bundgaard H, Bundgaard JS, Raaschou-Pedersen DET, von Buchwald C, Todsen T, Norsk J, et al. Effectiveness of adding a mask recommendation to other public health measures to prevent SARS-CoV-2 infection in Danish mask wearers. Ann Intern Med. 2021;174(3):335-43. Available from: https://doi.org/10.7326/M20-6817.
86. Leffler CT, Ing EB, Lykins JD, Hogan MC, McKeown CA, Grzybowski A. Association of country-wide coronavirus mortality with demographics, testing, lockdowns, and public wearing of masks. Am J Trop Med Hyg. 2020;103(6):2400-11. Available from: https://doi.org/10.4269/ajtmh.20-1015.
87. Eikenberry SE, Mancuso M, Iboi E, Phan T, Eikenberry K, Kuang Y, et al. To mask or not to mask: modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic. Infect Dis Model. 2020;5:293-308. Available from: https://doi.org/10.1016/j.idm.2020.04.001.
88. Ngonghala CN, Iboi E, Eikenberry S, Scotch M, MacIntyre CR, Bonds MH, et al. Mathematical assessment of the impact of non-pharmaceutical interventions on curtailing the 2019 novel Coronavirus. Math Biosci. 2020;325:108364. Available from: https://doi.org/10.1016/j.mbs.2020.108364.
89. Mitze T, Kosfeld R, Rode J, Wälde K. Face masks considerably reduce COVID-19 cases in Germany: a synthetic control method approach. Bonn, Germany: IZA Institute of Labour Economics; 2020 Jun. Available from: http://ftp.iza.org/dp13319.pdf.
90. Bouchnita A, Jebrane A. A multi-scale model quantifies the impact of limited movement of the population and mandatory wearing of face masks in containing the COVID-19 epidemic in Morocco. Math Model Nat Phenom. 2020;15:31. Available from: https://doi.org/10.1051/mmnp/2020016.
91. Catching A, Capponi S, Yeh MT, Bianco S, Andino R. Examining face-mask usage as an effective strategy to control COVID-19 spread. medRxiv. 2020 Aug 14. Available from: https://doi.org/10.1101/2020.08.12.20173047.
92. Fisman DN, Greer AL, Tuite AR. Bidirectional impact of imperfect mask use on reproduction number of COVID-19: a next generation matrix approach. Infect Dis Model. 2020;5:405-8. Available from: https://doi.org/10.1016/j.idm.2020.06.004.
93. Bielecki M, Züst R, Siegrist D, Meyerhofer D, Crameri GAG, Stanga Z, et al. Social distancing alters the clinical course of COVID-19 in young adults: a comparative cohort study. Clin Infect Dis. 2021;72(4):598-603. Available from: https://doi.org/10.1093/cid/ciaa889.
94. Gandhi M, Beyrer C, Goosby E. Masks do more than protect others during COVID-19: reducing the inoculum of SARS-CoV-2 to protect the wearer. J Gen Intern Med. 2020:1-4. Available from: https://doi.org/10.1007/s11606-020-06067-8.
95. Brainard J, Jones NR, Lake IR, Hooper L, Hunter PR. Community use of face masks and similar barriers to prevent respiratory illness such as COVID-19: a rapid scoping review. Euro Surveill. 2020;25(49):2000725. Available from: https://doi.org/10.2807/1560-7917.ES.2020.25.49.2000725.

96. Chou R, Dana T, Jungbauer R, Weeks C, McDonagh MS. Masks for prevention of respiratory virus infections, including SARS-CoV-2, in health care and community settings. Ann Intern Med. 2020 Aug 27. Available from: https://doi.org/10.7326/L20-1067.

97. European Centre for Disease Prevention and Control. Using face masks in the community: first update. Effectiveness in reducing transmission of COVID-19. Solna, Sweden: ECDC; 2021 Feb 21. Available from: https://www.ecdc.europa.eu/sites/default/files/documents/covid-19-face-masks-community-first-update.pdf.

98. Gupta M, Gupta K, Gupta S. The use of facemasks by the general population to prevent transmission of Covid 19 infection: a systematic review. medRxiv. 2020 May 6. Available from: https://doi.org/10.1101/2020.05.01.20087064.

99. Health Information and Quality Authority. Face mask use in the community to reduce SARS-COV-2 transmission – rapid evidence update. Dublin, Ireland: HIQA; 2020 Dec 17. Available from: https://www.hiqa.ie/reports-and-publications/health-technology-assessment/face-mask-use-community-reduce-sars-cov-2.

100. Public Health Ontario. 2019-nCoV – what we know so far about…wearing masks in public. Toronto, ON: Queen's Printer for Ontario; 2020 Apr 7. Available from: https://www.publichealthontario.ca/-/media/documents/ncov/covid-wwksf/what-we-know-public-masks-apr-7-2020.pdf?la=en.

101. Smith JD, MacDougall CC, Johnstone J, Copes RA, Schwartz B, Garber GE. Effectiveness of N95 respirators versus surgical masks in protecting health care workers from acute respiratory infection: a systematic review and meta-analysis. Can Med Assoc J. 2016;188(8):567-74. Available from: https://doi.org/10.1503/cmaj.150835.

102. Tabatabaeizadeh S-A. Airborne transmission of COVID-19 and the role of face mask to prevent it: a systematic review and meta-analysis. Eur J Med Res. 2021 Jan 21;26(1):1. Available from: https://doi.org/10.1186/s40001-020-00475-6.

103. Wei J, Doherty M, Persson MSM, Swain S, Kuo C, ZENG C, et al. Facemasks prevent influenza-like illness: implications for COVID-19. medRxiv. 2020 May 12. Available from: https://doi.org/10.1101/2020.05.07.20094912.

104. Xiao M, Lin L, Hodges JS, Xu C, Chu H. Double-zero-event studies matter: a re-evaluation of physical distancing, face masks, and eye protection for preventing person-to-person transmission of COVID-19 and its policy impact. J Clin Epidemiol. 2021 Feb 1. Available from: https://doi.org/10.1016/j.jclinepi.2021.01.021.

105. Aggarwal N, Dwarakanathan V, Gautam N, Ray A. Facemasks for prevention of viral respiratory infections in community settings: a systematic review and meta-analysis. Indian J Public Health. 2020;64(6):192-200. Available from: https://doi.org/10.4103/ijph.IJPH_470_20.

106. Dugré N, Ton J, Perry D, Garrison S, Falk J, McCormack J, et al. Masks for prevention of viral respiratory infections among health care workers and the public: PEER umbrella systematic review. Can Fam Physician. 2020;66(7):509-17. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/pmc7365162/.

107. Coclite D, Napoletano A, Gianola S, del Monaco A, D'Angelo D, Fauci A, et al. Face mask use in the community for reducing the spread of COVID-19: a systematic review. Frontiers in Medicine. 2021;7(1060). Available from: https://doi.org/10.3389/fmed.2020.594269.

108. Li Y, Liang M, Gao L, Ayaz Ahmed M, Uy JP, Cheng C, et al. Face masks to prevent transmission of COVID-19: a systematic review and meta-analysis. Am J Infect Control. 2020 Dec 18. Available from: https://doi.org/10.1016/j.ajic.2020.12.007.

109. Rohde D, Ahern S, Clyne B, Comber L, Spillane S, Walsh K, et al. Effectiveness of face masks worn in community settings at reducing the transmission of SARS-CoV-2: a rapid review [version 1; peer review: 1 approved with reservations]. HRB Open Res. 2020;3(76). Available from: https://doi.org/10.12688/hrbopenres.13161.1.

110. Koh E, Ambatipudi M, Boone DL, Luehr JBW, Blaise A, Gonzalez J, et al. Quantifying face mask comfort. medRxiv. 2021 Apr 6. Available from: https://doi.org/10.1101/2021.03.31.21254723.
111. Regli A, Sommerfield A, von Ungern-Sternberg BS. The role of fit testing N95/FFP2/FFP3 masks: a narrative review. Anaesthesia. 2021;76(1):91-100. Available from: https://doi.org/10.1111/anae.15261.
112. Sandaradura I, Goeman E, Pontivivo G, Fine E, Gray H, Kerr S, et al. A close shave? Performance of P2/N95 respirators in health care workers with facial hair: results of the BEARDS (Adequate Respiratory DefenceS) study. J Hosp Infect. 2020 Jan 21. Available from: https://doi.org/10.1016/j.jhin.2020.01.006.
113. Canadian Agency for Drugs and Technology in Health. Respirator device fit for individuals with facial hair. Ottawa, ON: CADTH; 2021 Feb 10. Available from: https://cadth.ca/sites/default/files/covid-19/RB1550%20COVID%20Facial%20hair%20v.6.03.pdf.
114. Huh YJ, Jeong HM, Lim J, Park HY, Kim MY, Oh HS, et al. Fit characteristics of N95 filtering facepiece respirators and the accuracy of the user seal check among Koreans. Infect Control Hosp Epidemiol. 2018 Jan;39(1):104-7. Available from: https://doi.org/10.1017/ice.2017.271.
115. Rothamer DA, Sanders S, Reindl D, Bertram TH. Strategies to minimize SARS-CoV-2 transmission in classroom settings: combined impacts of ventilation and mask effective filtration efficiency. medRxiv. 2021 Jan 4. Available from: https://doi.org/10.1101/2020.12.31.20249101.
116. Runde DP, Harland KK, Van Heukelom P, Faine B, O'Shaughnessy P, Mohr NM. The “double eights mask brace” improves the fit and protection of a basic surgical mask amidst COVID-19 pandemic. JACEP Open. 2021;2(1):e12335. Available from: https://doi.org/10.1002/emp2.12335.
117. Brooks J, Beezhold D, Noti J, Coyle J, Derk R, Blachere F, et al. Maximizing fit for cloth and medical procedure masks to improve performance and reduce SARS-CoV-2 transmission and exposure. Morb Mortal Wkly Rep. 2021;70:254-7. Available from: http://dx.doi.org/10.15585/mmwr.mm7007e1.
118. Abbasinia M, Karimie S, Haghighat M, Mohammadfam I. Application of nanomaterials in personal respiratory protection equipment: a literature review. Safety. 2018;4(4):47. Available from: https://doi.org/10.3390/safety4040047.
119. Huang L, Xu S, Wang Z, Xue K, Su J, Song Y, et al. Self-reporting and photothermally enhanced rapid bacterial killing on a laser-induced graphene mask. ACS Nano. 2020;14(9):12045-53. Available from: https://doi.org/10.1021/acsnano.0c05330.
120. Karmacharya M, Kumar S, Gulenko O, Cho Y-K. Advances in facemasks during the COVID-19 pandemic era. ACS Appl Bio Mater. 2021 Jan 14. Available from: https://doi.org/10.1021/acsabm.0c01329.
121. Talebian S, Wallace GG, Schroeder A, Stellacci F, Conde J. Nanotechnology-based disinfectants and sensors for SARS-CoV-2. Nat Nanotechnol. 2020;15(8):618-21. Available from: https://doi.org/10.1038/s41565-020-0751-0.
122. Health Canada. Masks/KN95 masks with biomass graphene (2021-04-08). Ottawa ON: Health Canada; 2021 Apr 15. Available from: https://www.healthycanadians.gc.ca/recall-alert-rappel-avis/hc-sc/2021/75391r-eng.php.
123. Health Canada. Face masks that contain graphene may pose health risks. Ottawa, ON: Health Canada; 2021 Apr 2. Available from: https://www.healthycanadians.gc.ca/recall-alert-rappel-avis/hc-sc/2021/75309a-eng.php.
124. Cheyns K, Mast J, Verleysen E, Waegeneers N. AgMask - evaluation of the types, efficient use and health risks of application of silver-based biocides to provide antimicrobial properties to face masks applied during the COVID-19 crisis. Brussels, Belgium: Sciensano, Belgian Institue for Health; 2021. Available from: https://www.sciensano.be/en/projects/evaluation-types-efficient-use-and-health-risks-application-silver-based-biocides-provide.
125. Li L, Zhao X, Li Z, Song K. COVID-19: performance study of microplastic inhalation risk posed by wearing masks. J Hazard Mater. 2021;411:124955. Available from: https://doi.org/10.1016/j.jhazmat.2020.124955.

126. Gandhi M, Marr LC. Uniting infectious disease and physical science principles on the importance of face masks for COVID-19. Med. 2021 Jan 15;2:29-32. Available from: https://doi.org/10.1016/j.medj.2020.12.008.
127. US Centers for Disease Control and Prevention. Improve the fit and filtration of your mask to reduce the spread of COVID-19. Atlanta GA: US Department of Health & Human Services; 2021 Apr 6. Available from: https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/mask-fit-and-filtration.html.
128. Alberta Health Services. COVID-19 Scientific Advisory Group rapid evidence report. Double masking & improved mask fit. Edmonton, AB: AHS; 2021 Mar 19. Available from: https://www.albertahealthservices.ca/assets/info/ppih/if-ppih-covid-19-sag-double-masking-improved-fit-rapid-review.pdf.
129. Sickbert-Bennett EE, Samet JM, Prince SE, Chen H, Zeman KL, Tong H, et al. Fitted filtration efficiency of double masking during the COVID-19 pandemic. JAMA Intern Med. 2021 Apr 16. Available from: https://doi.org/10.1001/jamainternmed.2021.2033.
130. Shah VP, Breeher LE, Hainy CM, Swift MD. Evaluation of healthcare personnel exposures to patients with severe acute respiratory coronavirus virus 2 (SARS-CoV-2) associated with personal protective equipment. Infect Control Hosp Epidemiol. 2021 May 12:1-5. Available from: http://doi.org/10.1017/ice.2021.219.
131. Deng W, Bao L, Gao H, Xiang Z, Qu Y, Song Z, et al. Ocular conjunctival inoculation of SARS-CoV-2 can cause mild COVID-19 in rhesus macaques. Nat Commun. 2020;11(1):4400. Available from: https://doi.org/10.1038/s41467-020-18149-6.
132. Ludwig-Begall LF, Wielick C, Dams L, Nauwynck H, Demeuldre PF, Napp A, et al. The use of germicidal ultraviolet light, vaporized hydrogen peroxide and dry heat to decontaminate face masks and filtering respirators contaminated with a SARS-CoV-2 surrogate virus. J Hosp Infect. 2020;106(3):577-84. Available from: https://doi.org/10.1016/j.jhin.2020.08.025.
133. Qing H, Yang Z, Shi M, Zhang Z. New evidence of SARS-CoV-2 transmission through the ocular surface. Graefes Arch Clin Exp Ophthalmol. 2020. Available from: https://doi.org/10.1007/s00417-020-04726-4.
134. Xia J, Tong J, Liu M, Shen Y, Guo D. Evaluation of coronavirus in tears and conjunctival secretions of patients with SARS-CoV-2 infection. J Med Virol. 2020 Jun;92(6):589-94. Available from: https://doi.org/10.1002/jmv.25725.
135. Perencevich EN, Diekema DJ, Edmond MB. Moving personal protective equipment into the community: face shields and containment of COVID-19. JAMA. 2020;323(22):2252-3. Available from: https://doi.org/10.1001/jama.2020.7477.
136. Lindsley WG, Noti JD, Blachere FM, Szalajda JV, Beezhold DH. Efficacy of face shields against cough aerosol droplets from a cough simulator. J Occup Environ Hyg. 2014 Aug;11(8):509-18. Available from: https://doi.org/10.1080/15459624.2013.877591.
137. Ronen A, Rotter H, Elisha S, Sevilia S, Parizer B, Hafif N, et al. Investigation of the protection efficacy of face shields against cough aerosol droplets. medRxiv. 2020 Oct 11. Available from: https://doi.org/10.1101/2020.07.06.20147090.
138. Roberge RJ. Face shields for infection control: a review. J Occup Environ Hyg. 2016;13(4):235-42. Available from: https://doi.org/10.1080/15459624.2015.1095302.
139. 3M. Filtering facepiece respirators FAQ: healthcare. St. Paul MN: 3M; 2020 Sep. Available from: https://multimedia.3m.com/mws/media/1792732O/respiratory-protection-faq-healthcare.pdf.
140. Chang JC, Johnson JS, Olmsted RN. Demystifying theoretical concerns involving respirators with exhalation valves during COVID-19 pandemic. Am J Infect Control. 2020 Aug 25;48(12):1564-5. Available from: https://doi.org/10.1016/j.ajic.2020.08.031.
141. Chughtai AA, Stelzer-Braid S, Rawlinson W, Pontivivo G, Wang Q, Pan Y, et al. Contamination by respiratory viruses on outer surface of medical masks used by hospital healthcare workers. BMC Infect Dis. 2019;19(1):491. Available from: https://doi.org/10.1186/s12879-019-4109-x.

142. Liu Y, Ning Z, Chen Y, Guo M, Liu Y, Gali NK, et al. Aerodynamic characteristics and RNA concentration of SARS-CoV-2 aerosol in Wuhan hospitals during COVID-19 outbreak. Nature. 2020 Mar 10;582(7813):557-60. Available from: https://doi.org/10.1038/s41586-020-2271-3.
143. MacIntyre CR, Chughtai AA, Rahman B, Peng Y, Zhang Y, Seale H, et al. The efficacy of medical masks and respirators against respiratory infection in healthcare workers. Influenza Other Respir Viruses. 2017;11(6):511-7. Available from: https://doi.org/10.1111/irv.12474.
144. European Centre for Disease Prevention and Control. Cloth masks and mask sterilisation as options in case of shortage of surgical masks and respirators Solna, Sweden: ECDC; 2020 [updated 2020 Mar 26]; Available from: https://www.ecdc.europa.eu/en/publications-data/cloth-masks-sterilisation-options-shortage-surgical-masks-respirators.
145. Viscusi DJ, Bergman MS, Eimer BC, Shaffer RE. Evaluation of five decontamination methods for filtering facepiece respirators. Ann Occup Hyg. 2009;53(8):815-27. Available from: https://doi.org/10.1093/annhyg/mep070.
146. Chughtai AA, Seale H, Chi Dung T, Maher L, Nga PT, MacIntyre CR. Current practices and barriers to the use of facemasks and respirators among hospital-based health care workers in Vietnam. Am J Infect Control. 2015;43(1):72-7. Available from: https://doi.org/10.1016/j.ajic.2014.10.009.
147. Schwartz A, Stiegell M, Greeson N, Vogel A, Thomann W, Brown M, et al. Decontamination and reuse of N95 respirators with hydrogen peroxide vapor to address worldwide personal protective equipment shortages during the SARS-CoV-2 (COVID-19) pandemic. Appl Biosaf. 2020;25(2):67-70. Available from: https://doi.org/10.1177/1535676020919932.
148. US Food and Drug Administration. Investigating decontamination and reuse of respirators in public health emergencies. Silver Spring, MD: US FDA; 2020 [updated Apr 10]; Available from: https://www.fda.gov/emergency-preparedness-and-response/mcm-regulatory-science/investigating-decontamination-and-reuse-respirators-public-health-emergencies.
149. Public Health Ontario. COVID-19 – what we know so far about… reuse of personal protective equipment Toronto, ON: Queen's Printer for Ontario; 2020 Apr 4. Available from: https://www.publichealthontario.ca/-/media/documents/ncov/covid-wwksf/what-we-know-reuse-of-personal-protective-equipment.pdf?la=en.
150. Health Canada. Optimizing the use of masks and respirators during the COVID-19 outbreak. Ottawa, ON: Health Canada; 2020 [updated Oct 20]; Available from: https://www.canada.ca/en/health-canada/services/drugs-health-products/medical-devices/masks-respirators-covid19.html.
151. World Health Organization. Advice on the use of masks for children in the community in the context of COVID-19. Geneva, Switzerland: WHO; 2020 Aug 21. Available from: https://www.who.int/publications/i/item/WHO-2019-nCoV-IPC_Masks-Children-2020.1.
152. Eberhart M, Orthaber S, Kerbl R. The impact of face masks on children - a mini review. Acta Paediatr. 2021 Feb 3. Available from: https://doi.org/10.1111/apa.15784.
153. Public Health Agency of Canada. COVID-19 and people with disabilities in Canada. Ottawa, ON: PHAC; 2021 Feb 9. Available from: https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/guidance-documents/people-with-disabilities.html.
154. US Centers for Disease Control and Prevention. Considerations for wearing masks. Atlanta, GA: US Department of Health & Human Services; 2020 Aug 7. Available from: https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/cloth-face-cover-guidance.html.
155. Scientific Advisory Group for Emergencies. Application of physical distancing and fabric face coverings in mitigating the B117 variant SARS-CoV-2 virus in public, workplace and community. London, UK: UK Government; 2021 Jan 29. Available from: https://www.gov.uk/government/publications/emg-application-of-physical-distancing-and-fabric-face-coverings-in-mitigating-the-b117-variant-sars-cov-2-virus-in-public-workplace-and-community.
156. US Centers for Disease Control and Prevention. When you've been fully vaccinated. Atlanta, GA: US Department of Health & Human Services; 2021 May 13. Available from: https://www.cdc.gov/coronavirus/2019-ncov/vaccines/fully-vaccinated.html.

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655 W. 12th Ave., Vancouver, BC, V5Z 4R4
contact@ncceh.ca | www.ncceh.ca