UK Health Security Agency

The role of face coverings in mitigating the transmission of SARS-CoV-2

An overview of evidence

Contents

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Summary

This paper draws on review-level evidence (searches up to 28 April 2021) to consider the potential effectiveness of face coverings in mitigating transmission of SARS-CoV-2. It includes evidence examining:

- the role of airborne transmission in relation to SARS-CoV-2
- the transmissibility of new SARS-CoV-2 variants
- the effectiveness of face coverings, including efficacy of different types of face coverings and factors that may impact on this

Current evidence on the potential for airborne transmission of SARS-CoV-2 is heterogeneous and mainly based on environmental sampling studies, modelling studies and outbreak investigations. While sampling studies suggest that SARS-CoV-2 can be detected in the environment, they usually do not provide evidence on infectiousness of the aerosols. Evidence from outbreak investigations suggests that long distance airborne transmission can occur and when it happens, it is usually in poorly ventilated indoor settings where the potential primary and secondary cases have stayed for extended durations of time. Other factors such as air flow or singing might also be contributing factors for long distance airborne transmission. Airborne transmission can also occur in healthcare settings, although it might predominantly happen during aerosol generating procedures.

Evidence on the transmissibility of new variants of concern is still in its early stages and based on a small number of low-quality reviews. The available evidence suggests an increased transmissibility for Alpha variant (B.1.1.7), although the magnitude of reported increase varies by geographic region, modelling approach, relative transmissibility of concurrent circulating strains and current control measures in place. The evidence available for Beta (B.1.351) and Gamma (P.1) variants is more limited but does also suggest an increased transmissibility (Delta/B.1617.2 variant was not considered). The biological mechanism of the increase in transmissibility is not yet clear though for Alpha variant (B.1.1.7) the most likely explanations are increased viral load and lower average infectious dose required to start infection.

The current evidence on face coverings suggests that all types of face coverings are, to some extent, effective in reducing transmission of SARS-CoV-2 in both healthcare and community settings. N95 respirators are likely to be the most effective, followed by surgical masks, and then non-medical masks, although optimised non-medical masks made of 2 or 3 layers might have similar filtration efficiency to surgical masks. The evidence specific to coronavirus disease 2019 (COVID-19) is still limited and does not allow for firm conclusions to be drawn for specific settings and type of face coverings. Wider evidence from other respiratory viruses suggests that, in healthcare settings, N95 respirators might be more effective than surgical masks in reducing infection risk.

Evidence mainly based on laboratory studies suggests that face coverings should be well-fitted to increase effectiveness.

No evidence on the effectiveness of face coverings against specific variants of SARS-CoV-2 was identified.

More research is needed to fully understand the contribution of airborne transmission to the COVID-19 pandemic and factors that may influence this. More robust research from well-designed intervention studies is also needed to better understand the effectiveness of different types of face coverings in mitigating the risk of different modes of transmission across settings. Finally, more research is needed to improve knowledge on how face coverings are used by subgroups of the population across settings and how this might impact on their effectiveness.

Purpose

This paper has been prepared for the Respiratory Evidence Panel. Its purpose is to enable access to the best available evidence related to the potential role of face coverings in mitigating the transmission of SARS-CoV-2. Evidence (searches up to 28 April 2021) was considered from across 3 core areas which were:

- the role of airborne transmission in relation to SARS-CoV-2
- the transmissibility of new SARS-CoV-2 variants
- the effectiveness of face coverings, including efficacy of different types of face coverings and factors that may impact on this

Earlier iterations of this paper were presented to and discussed by the Respiratory Evidence Panel on 21 April 2021 and 12 May 2021.

Introduction

COVID-19 is a respiratory disease which is transmitted through respiratory particles that contain the SARS-CoV-2 virus. Person-to-person transmission mainly occurs by direct transmission of droplets (respiratory particles with ballistic trajectory that directly deposit on mucous membranes) and by airborne transmission of aerosols (respiratory particles that remain suspended in the air and can be inhaled) (1); although the extent to which airborne transmission occurs is still unknown and is the subject of extensive discussion and controversy in the scientific community.

In a recent publication (2), Milton has attempted to define respiratory particle ranges based on their behaviour in the air. The threshold between droplets and aerosols was set at 100 microns, with ballistic droplets being particles larger than 100 microns. Nasopharyngeal aerosols are between 15 and 100 microns and will remain suspended in the air for short distances (usually less than 2 metres) unless air velocities are high. Smaller aerosols can remain airborne for distances greater than 2 metres and, when inhaled, can penetrate deeper than the nasopharyngeal cavity: thoracic aerosols (5 to 15 microns) can penetrate to the thorax and respirable aerosols (< 5 microns) can penetrate up to the lung (2).

In the UK, the definitions used by Public Health England (PHE) and the Scientific Advisory Group for Emergencies (SAGE) are based on work by Milton (100 microns threshold between droplets and aerosols) (1, 2), whereas the World Health Organization (WHO) threshold is set at 5 to 10 microns (3).

Regardless of terminology, a crucial consideration for public health and mitigation measures is that virus-laden respiratory particles can be inhaled directly from the air, and that this is more likely to happen at short range (where the concentrations of particles is higher) than at long distance (4). Therefore, close contact transmission (< 2 metres) is expected to be the main transmission mode, whether it is through direct contact with ballistic particles or through inhalation of particles suspended in the air. Risk of transmission at greater distance is considered to be low outside (5, 6), but there are still some uncertainties about transmission risk indoors, where respiratory particles from an infectious individual could remain suspended in the air for longer, particularly in poorly-ventilated spaces (7). Whilst some risk of transmission via fomites (where transmission occurs through contact with infectious virus on surfaces) has been acknowledged, the risk is thought to be low compared to direct transmission and airborne transmission (8).

Over recent months, several novel variants of SARS-CoV-2 have emerged as the virus continues to spread globally. Up to the end of March 2021, 3 variants have been identified as ‘variants of concern’ (VOC) due to mutations which could potentially impact transmission, severity, reinfection and vaccine effectiveness. These include the variants Alpha (B.1.1.7; first identified in the UK), Beta (B.1.351; first identified in South Africa) and Gamma (P.1; first identified in Brazil). There is a need to examine the extent to which new variants may be more transmissible and consider any difference in transmission modes which may impact on the effectiveness of certain mitigation measures.

Face coverings (defined within the UK as any type of face covering that covers the mouth and the nose, including medical masks and other types of masks) are one means of mitigating against respiratory transmission of SARS-CoV-2. Face coverings are thought to reduce respiratory virus transmission largely through intercepting and limiting the spread of virus-laden droplets ('droplet transmission') produced by the mask wearer ('source control', and this is how they have traditionally been used in healthcare settings) and, to a lesser extent, filtering the air the mask-wearer inhales ('wearer protection') (9). However, the role of face coverings in mitigating airborne transmission is still unclear. Other mitigation measures for airborne transmission include eye protection and ventilation although these will not be discussed in this paper.

N95 respirators (or their equivalent FFP2) and surgical masks (also called 'medical masks') play a role in controlling infection in clinical settings when used as part of a comprehensive package of infection control measures. They are intended to be worn by healthcare professionals in order to protect patients and must meet the design and safety requirements of the Medicines and Healthcare products Regulatory Agency (MHRA) (10). The WHO recommends that in areas of known or suspected transmission of SARS-CoV-2, non-medical masks should be worn by the public when indoors, as well as outdoors if physical distancing is not possible. Medical masks should be used by certain vulnerable groups, where social distancing cannot be achieved, based on levels of risk (11).

Non-medical masks are typically made of fabric or cloth, can be homemade or commercially produced, and may be reusable or disposable (11). WHO guidance recommends that they should be made of 3 layers, including hydrophobic and hydrophilic materials (11). In England, the recommendation is that face coverings should be worn in indoor settings, they should be made of at least 2 layers and form a good fit around the face to cover the mouth and the nose (12). Non-medical masks can vary in filtration efficiency depending on the materials used and the number of layers.

During the early stages of the COVID-19 pandemic, evidence examining the effectiveness of face coverings in community settings was largely drawn from the use of medical masks in reducing transmission of influenza and other coronaviruses (specifically SARS-CoV-1 and MERS) (13 to 17). The evidence for their effectiveness was inconclusive, although this could have been because it was derived from different settings (pandemic versus non-pandemic contexts) and based on different types of studies. None of these early reviews identified studies directly related to COVID-19.

Despite the high levels of interest in this topic, the evidence on the effectiveness of face coverings to reduce transmission of SARS-CoV-2 is still limited, largely due to the low level of evidence provided by the studies available (which are largely observational, and not always peer-reviewed) and by the differences between studies in terms of methods and settings. Factors such as types of face coverings, mask fit, and compliance with face covering policies may also impact on their effectiveness, especially in the context of airborne transmission. With the emergence of new and potentially more transmissible variants, there is a need to consider whether non-medical masks offer enough protection. It has been suggested that surgical masks or even ‘double-masks’ (made of one medical mask and one non-medical mask) should be used instead of non-medical masks in community settings.

This paper sets out evidence to consider the potential effectiveness of face coverings in mitigating transmission of SARS-CoV-2, including consideration of:

- the role of airborne transmission in relation to SARS-CoV-2
- the transmissibility of new SARS-CoV-2 variants
- the effectiveness of face coverings, including efficacy of different types of coverings and factors that may impact on this

A glossary of the terms used in this paper is provided in Annex 1.

Methods

Searches were conducted separately for each of the 3 core topics (airborne transmission, new variants, and face coverings) on 9 March 2021 to identify any recent and relevant review-level evidence. An additional search was conducted on 28 April 2021 to identify systematic reviews focusing on COVID-19 evidence on face coverings effectiveness in healthcare settings. The list of COVID-19 review repositories searched is provided in Annex 2.

Potentially relevant reviews were screened by 2 reviewers and selected for inclusion if they were considered directly relevant to the topic. Disagreements were resolved by discussion between the 2 reviewers and where more than one review was identified, decisions around inclusion focused on recency of searches, review quality and review question. The quality of included reviews was assessed using AMSTAR 2, a tool to assess the quality of systematic reviews (18).

Relevant papers from Scientific Advisory Group for Emergencies (SAGE), the New and Emerging Respiratory Virus Threats Advisory Group (NERVTAG) and the Scientific Pandemic insights Group on Behaviours (SPI-B) were included as additional evidence where relevant. Additional evidence identified by topic expert members of the Respiratory Evidence Panel was also considered.

Whilst there is a larger body of evidence from other respiratory viruses on airborne transmission and the effectiveness of face coverings in healthcare and community settings, only reviews focusing on evidence from the COVID-19 pandemic were considered for this paper. Some of the included reviews considered wider evidence (especially from other respiratory viruses), but this was not part of the search strategy which was focused on COVID-19 evidence.

A narrative summary is provided for each topic and summaries of each included review are presented in evidence tables at the end of this document. Conclusions were drawn based on the evidence presented and informed by discussions of the Respiratory Evidence Panel. Knowledge gaps were identified and summarised.

Airborne transmission of SARS-CoV-2 virus

Evidence identified (Evidence table 1)

Several systematic and rapid reviews have examined the role of airborne transmission of SARS-CoV-2; the 2 most recent and relevant reviews are reported here. The systematic review with the most recent search date (up to 20 December 2020) assessed the potential of airborne transmission by focusing on field studies that included air sampling (19). In total 22 reviews and 67 primary studies were included. While the review contained evidence tables of each primary study as well as summary tables of the results of the RT-PCR studies and of live culture studies, it lacks high-level synthesis and it was not possible to extract results by setting (healthcare versus community). This review was rated medium for quality and includes evidence from both healthcare and community settings. It is available as a preprint and, as per peer-review decision from 24 March 2021, had been approved with reservation by one reviewer and not approved by 2 other reviewers.

A rapid review conducted by the Public Health Agency in Canada (PHAC) (20) (search date up to 6 November 2020; not peer-reviewed) included 57 primary studies. Any study design was included, so a wider body of evidence is considered, and results were presented as:

- i) epidemiological evidence of airborne transmission
- ii) experimental evidence of virus viability in aerosols
- iii) presence of virus in exhaled breath
- iv) viral load in respiratory particles
- v) fluid dynamic models

This review rated low for quality, mainly due to the lack of risk of bias assessment. An update of this review (search date up to 12 March 2021) which included 46 new primary studies was also considered although fluid dynamic modelling studies were not included (21). The update was rated critically low for quality, mainly due to the lack of risk of bias assessment and discussion of possible biases.

The 2 reviews combined summarised evidence on airborne transmission from multiple disciplines and across different study designs and methodological approaches, including outbreak investigations, biological monitoring studies (exhaled breath and environmental sampling), laboratory studies (virus stability and viability in aerosols) and modelling studies (viral load and fluid dynamic simulations). Most air sampling studies were based on RT-PCR detection, which does not distinguish between live or dead virus, or viral fragments. Modelling studies provide useful information on the physics of how respiratory particles can behave and on the impact of environmental conditions; but these studies are limited by the validity of their assumptions and do not always consider real-world settings. Outbreak investigations are descriptive retrospective observational studies, which limits the inferences about airborne transmission to circumstantial evidence. However, this is possibly the best evidence currently available to assess the risk of airborne transmission in real-world settings.

Results

Both reviews identified a number of air sampling studies that showed that SARS-CoV-2 can be detected in the environment in a number of real-world settings, including community and healthcare settings, but this was mainly based on RT-PCR testing (19, 21). Heneghan and others identified 10 studies that performed viral culture (mainly from air samples in healthcare settings), of which only 3 detected viable (infectious) SARS-CoV-2 virus (2 in hospitals and one in a student healthcare centre) (19). Similarly, the PHAC review identified only 4 studies that detected viable SARS-CoV-2 virus in the environment: 3 studies detected viable SARS-CoV-2 in healthcare settings (2 of these are also included in the Heneghan and others review), and one detected viable virus from air sample collected in a car in which a mildly symptomatic case was present (21). To note that in these 4 studies the air samples had been collected at less than 2 metres from the infected individuals (21).

Based on these sampling studies, Heneghan and others reported that while SARS-CoV-2 RNA had been detected in the air in various settings, they stated that firm conclusions on airborne transmission could not be drawn due to the lack of evidence on presence of infectious samples (19).

In addition to sampling studies, the PHAC rapid review reported evidence from experimental studies in laboratory settings that showed that SARS-CoV-2 can remain viable in artificially generated aerosols up to 16 hours and that the stability and infectiousness of SARS-CoV-2 in artificial aerosols was dependent on sunlight, temperature and humidity (21). Evidence from modelling studies suggesting that aerosols containing SARS-CoV-2 can remain suspended in the air for prolonged periods and can be dispersed beyond 2 metres; that smaller particles are likely to remain suspended in the air for extended periods of time and to travel greater distance; and that additional factors such as air flow could increase dispersion but also lead to accumulation of respiratory particles in the absence of ventilation (20). In relation to infectiousness of respiratory particles, the evidence suggests that the concentration of virus in respiratory particles depends on the viral load of the infected person but that the quantity of respiratory particles expelled varies between individuals and depends on the activity (for example breathing, coughing, speaking or singing) (21).

The PHAC review also assessed epidemiological evidence of airborne transmission by analysing data from 19 COVID-19 clusters in different community settings, including restaurant, public buses, apartment buildings, sport facilities, choir practice settings and shopping centres. Based on these studies, the PHAC review concluded that airborne transmission of SARS-CoV-2 may have occurred in some settings, usually in poorly ventilated or crowded indoor spaces, where the index cases and potential infected cases stayed for an extended duration of time; and that factors such as suboptimal ventilation, lack of air circulation and indoor air currents might have facilitated dispersion of infected respiratory particles (21). The evidence suggests that in some of these outbreaks the primary cases were pre-symptomatic or early symptomatic or that the individuals were engaged in activities such as singing or exercise at the time of transmission (21). The review authors noted in the original version of the review (not discussed in the update) that the evidence on airborne transmission was of low quality, although this was based on study design considerations (20). The risk of bias of individual studies was not assessed.

In addition to these 2 reviews, evidence can be drawn upon from a review conducted jointly by British Infection Association (BIA), Healthcare Infection Society (HIS), Infection Prevention Society (IPS) and Royal College of Pathologists (RCPath) to inform UK guidance (22). This review of the evidence considered the different transmission routes of SARS-CoV-2 with a focus on healthcare settings although the evidence was not limited to these settings. The authors of this review concluded that the airborne transmission route was possible, although they noted that it may be circumstance-specific, such as during aerosol generating procedures. To note that this review was published on 30 April 2021 (after the searches conducted for this paper) and that the evidence assessed in this review in relation to airborne transmission was mostly included in the reviews identified in this summary paper. This review has therefore not been included in the evidence tables.

Conclusions

Current evidence on the potential for airborne transmission of SARS-CoV-2 is heterogeneous and mainly based on air sampling studies, modelling studies and outbreak investigations which limits the inferences about airborne transmission to circumstantial evidence. The overall body of evidence suggests that long distance airborne transmission (beyond 2 metres) is possible and that when it happens, it is usually in poorly ventilated indoor settings where the index cases and potential infected cases stayed for an extended duration of time. Other factors such as air flow or activities such as singing and exercise might also be contributing factors for airborne transmission. However, the evidence currently available does not allow for an assessment of whether short range airborne transmission is predominant compared to direct transmission via droplets. Airborne transmission can also occur in healthcare settings, although it might predominantly happen during aerosol generated procedures. Therefore, the overall contribution of airborne transmission to the COVID-19 pandemic is still unclear.

More research is needed to improve knowledge on the viability and infectivity of SARS-CoV-2 in in short- and long-range respiratory aerosols, and how environmental factors (such as temperature and humidity) impact these results. More research is needed to assess the dose-response for SARS-CoV-2 in respiratory particles, how and when these are generated by individuals infected with SARS-CoV-2 virus, and when the peak of infectivity occurs for aerosol generation. There is a need for higher quality studies to determine airborne transmission risk in real-world settings.

Variants of concern

Evidence identified (Evidence table 2)

Several novel variants of SARS-CoV-2 have emerged and as of late 2020, 3 key variants of concern (VOC) have been identified (Alpha/B.1.1.7, Beta/B.1.351 and Gamma/P.1). These VOC can potentially impact transmission, disease severity, reinfection and vaccine effectiveness, although evidence for these is still emerging. While there is some review-level evidence available, these are mainly evidence summaries that have been conducted at pace by public health agencies and are of low methodological quality (but still provide relevant and useful information). The focus of this paper is not to discuss the impact of individual mutations but rather to assess the overall evidence available for specific VOC.

In this context, the 4 most recent rapid reviews identified on VOC have been included, all of them rated critically low for quality (mainly due to the lack of risk of bias assessment and discussion). One was a rapid scoping review conducted by Curran and others that included evidence on the 3 main VOC (search date up to 21 February 2021) (23). This review included 23 studies (13 preprints) and the main outcomes for transmission were the basic (R0) and effective (Rt) reproduction number, VOC growth rate and data related to risk of transmission and changes in transmission.

The 3 other reviews were evidence syntheses conducted by Public Health Ontario, one on each VOC: Alpha/B.1.1.7 (search date up to 15 February 2021) (24), Beta/B.1.351 (search date up to 4 February 2021) (25) and Gamma/P.1 (search date up to 2 February 2021) (26). The number of studies included in each review was not specified, although primary studies overlap between these reviews and the review by Curran and others was checked to ensure that each review did include unique studies (see Evidence Table 3).

Results on the Alpha variant (B.1.1.7)

The rapid scoping review by Curran and others identified 20 studies which reported on the Alpha variant (B.1.1.7) (23). Transmission risk for the Alpha variant was estimated to be 45 to 71% higher than in previously circulating variants. For example, one study conducted in the UK estimated the Alpha variant to be 52% more transmissible than previous variants based on SARS-CoV-2 sequencing data and COVID-19 surveillance data from 94,934 cases between 1 August 2020 and December 2020. Two additional studies (also conducted in the UK) found that the basic reproduction number (R0) of the Alpha variant was 75 to 78% higher compared to non-VOC. A further 6 studies (3 UK, one Israel, 2 international) reported effective reproduction number (Rt) values ranging from 1.1 to 2.18. An additive transmission effect was observed, as the Alpha variant not only replaced previous variants but was associated with an increase in the number of infections.

Similarly, findings from the Public Health Ontario review suggested that the Alpha variant is more transmissible than other non-VOC (24). This was based on the following observations: a rapid rise in incidence and higher secondary attack rates; a higher Rt; a higher viral load and an increased affinity with ACE2 receptor which is used by SARS-CoV-2 for cell entry. Data comparing the secondary attack rates for Alpha and non-Alpha variants in England between 5 October and 6 December 2020 found a secondary attack rate of 15.1% for index cases with Alpha variant, compared to 9.8% for index cases with non-Alpha variants.

Results on the Beta variant (B.1.351)

The rapid review by Curran and others identified 3 documents that reported on the Beta variant (B.1.351) (23). One study included data on transmissibility, suggesting that it was 55% more transmissible than previously circulating variants. The review authors reported, based on a CDC document, that the detection of the Beta variant coincided with a rapid rise in confirmed cases in Zambia and South Africa but no data on the rate of transmission was reported. The review authors noted that the evidence was too limited to draw conclusions on transmissibility of B1.351.

The Public Health Ontario review reported preliminary results from an additional study conducted in South Africa, whereby the Beta variant was estimated to be 50% more transmissible than previously circulating variants (25). These results are in line with those reported in Curran and others.

Results on the Gamma variant (P.1)

The rapid review by Curran and others identified 3 documents on for the Gamma variant (P.1), of which 2 reported on transmissibility (23). In one study, the Gamma variant was estimated to be 1.4 to 2.2 times more transmissible compared to previously circulating variants using dynamic modelling integrating genomic and mobility data. The other study reported Gamma variant prevalence in the Amazonas state, suggesting an increase from 0% in November 2020 to 73% in January 2021. The review authors noted that the evidence was too limited to draw conclusions on transmissibility.

The Public Health Ontario review identified one additional study on the Gamma lineage, which also estimated a higher transmissibility then pre-existing lineages in Manaus, Brazil (26). In this study, 42% of samples sequences from a cluster of cases in December 2020 were found to be of the Gamma lineage, compared to 0% in samples collected between March to November 2020.

Reasons attributed to increased transmissibility

Overall, the rapid reviews found some evidence to suggest there may be an increase in viral load (using RT-PCR Ct values as a proxy measure) for the Alpha variant (23, 24); however, there was variation between the studies on the methodology and outcomes. No data on viral load was reported for the Beta and Gamma variants.

There is some evidence that the N501Y mutation in the Alpha lineage may increase infectivity by enhancing spike protein binding to ACE2 receptors (23, 24). One in vitro study found that the Alpha variant had an approximately 10 times greater affinity for ACE2 than previously circulating variants (23).

In addition to the reviews identified for this section, a recent NERVTAG paper (22 April 2021) suggested with moderate confidence that the higher growth rate of the Alpha variant was due to an increase in transmissibility (rather than a reduced serial interval) (27). The most likely explanations for the competitive advantage of Alpha over other variants were reported to be a lower average infectious dose required to start infection (reported with low confidence) and an increased viral load inferred from lower Ct values (reported with low confidence). Data was inconclusive in relation to the emission of viral variants into the environment by infected individuals, although that data does suggest that the environmental survival of the Alpha variant is similar to other variants (reported with moderate confidence).

Conclusion

The evidence on VOC is still emerging and the review-level evidence available is mainly based on non-peer-reviewed evidence summaries of low methodological quality. Although the evidence suggests an increase in transmissibility for the Alpha variant (B.1.1.7), the magnitude of reported increase varies by geographic region, modelling approach, relative transmissibility of concurrent circulating strains and current control measures in place. The evidence available for the VOC Beta (B.1.351) and Gamma (P.1) was more limited, although it does also suggest an increased transmissibility.

The biological mechanism of the increase in transmissibility is not yet clear and more research is needed. For the Alpha variant (B.1.1.7) the most likely explanations to date are increased viral load (inferred from lower Ct values) and lower average infectious dose required to start infection.

The paper was drafted before the Delta variant (B1.617.2) was classified as a VOC and no information on its transmissibility was available at the time.

Face coverings

Evidence identified (Evidence table 3)

Many systematic or rapid reviews on the effectiveness of face coverings in mitigating transmission of SARS-CoV-2 have been published since the start of the pandemic, although they vary in quality and focus (healthcare or community, COVID-19 evidence only or consideration of other respiratory viruses, and so on), and some are out of date with searches dating back as early as April 2020. Five reviews reporting on face coverings effectiveness are summarised; selected based on search dates, quality and review question.

The review with both the most recent search date (up to 2 February 2021) and highest quality was a living review by Chou and others (28 to 33) which aimed at assessing the effectiveness of face coverings (N95 respirators, surgical masks and non-medical masks) for preventing respiratory virus infection (including SARS-CoV-2). This review, rated high for quality, included evidence from both healthcare and community settings but limited the evidence to be included to peer-reviewed evidence from randomised trials and observational studies (cohort, case-control and cross-sectional). An additional systematic review by Kim and others (with network meta-analysis; random-effect; search date up to October 2020) was identified (34) but was not formally included as it is published as a preprint and some essential information (such as the list of included studies) will not be available until peer-reviewed publication. The scope of this review is similar to Chou and others (the main difference is the inclusion of preprints) so it is expected that overlap in primary studies between the 2 reviews will be important. However, the evidence has been GRADEd and the results of the meta-analyses are of interest if considered alongside the results by Chou and others.

A systematic review by Tian and others aiming at identifying risk factors and protective measures (including face coverings) for healthcare workers during viral respiratory epidemics (SARS, MERS, SARS-CoV-2, A H1N1 and H5N1) was identified (35). The search date was July 2020, but it was nonetheless deemed relevant as it considers wider evidence than Chou and others (such as cross-sectional studies, as well as preprint manuscripts). Five studies specific to face coverings and COVID-19 were identified in this review, of which only 2 were also included in Chou and others. This systematic review, which included meta-analyses, was rated medium for quality.

A PHE rapid review on the effectiveness and efficacy of face coverings to reduce transmission of SARS-CoV-2 in community settings included studies published up to 22 September 2020 (36). It rated low for quality, mainly due to the lack of formal risk of bias assessment although individual studies were critically appraised. This review assessed a wider range of evidence than Chou and others as it includes ecological and laboratory studies as well as preprints.

Two additional relevant evidence summaries (not peer-reviewed) were identified: one conducted by the evidence-based centre ECRI (search date up to 16 February 2021) (37) and one by the Alberta Health Service (search date up to 22 February 2021) (38). Both rated critically low for quality (mainly due to the lack of risk of bias assessment and discussion) but were deemed of interest for this overview of the evidence as their search dates were more recent than Chou and others and because of the relevance of their review questions. Indeed, both reviews focused on community settings and, in terms of types of face coverings, the ECRI review focused on non-medical masks and the review by the Alberta Health Service on double-masking.

Despite the large number of primary studies and reviews published on face coverings and COVID-19, the evidence remains mainly limited to observational and laboratory studies, except for one randomised controlled trial (RCT), and do not always specify the type of face covering used, the comparators (no face covering, other types of face covering, other frequency of use, and so on), the setting (such as high risk versus low risk settings or specific care areas) and whether face coverings were used as source control or wearer protection. Observational studies may be influenced by selection bias (such as non-representative sample due to voluntary participation the study) and recall bias, and additional source of infection to the ones considered in the study cannot be ruled out. In addition, ecological studies (population-based observational studies) provide results at population level that may not apply at individual level and the results may be highly correlated with other transmission-control measures. Finally, laboratory studies provide mechanistical evidence and do not always take into account real-world conditions. Due to the heterogeneity of laboratory studies, including differences in testing methods and materials used, it is not always possible to directly compare the results of studies, nor to reliably assess the efficacy of each material as a function of the number of layers.

A summary of the findings on effectiveness of face coverings specific to COVID-19 is presented in Table 1 below.

Only one review providing evidence on face coverings use and behaviour was identified. This review, a systematic review with meta-analysis by Bakhit and others which rated high for quality, aimed at evaluating the downsides of wearing face coverings in healthcare and community settings (39). Only 2 of the 37 included studies were conducted during the COVID-19 pandemic (search date: 18 May 2020).

Results on effectiveness of face coverings

All settings

Filtration efficiency of different face coverings or different materials has mainly been assessed through laboratory studies which provide mechanistical evidence. Very few of the laboratory studies used human participants (although most used manikins) and those that did used small numbers (maximum n = 4). N95 respirators are likely to have the highest filtration efficiency, followed by surgical masks and then non-medical masks, although optimised non-medical masks made of 2 or 3 layers might have similar efficiency than surgical masks (36, 38). It is expected that all non-medical masks would provide some level of protection, although combining 3 layers of different materials appears to improve filtration efficiency (36 to 38). Only one review (based on one laboratory study) reported evidence on double-masking, suggesting that it was associated with a reduction in exposure to particles (38). However, using one unique face covering made of several layers might have similar efficiency to a double mask.

Evidence from laboratory studies suggest that all face coverings material provide some protection through filtration of both droplets and aerosols compared to no face coverings, although different fabrics varied in their ability to filter droplets or aerosols of different sizes (36).

The relative risks (RR) for SARS-CoV-2 infection were calculated for different types of face coverings (versus no face coverings; including evidence from both healthcare and community settings) by Kim and others in a network meta-analysis including published and unpublished randomised controlled trials (RCTs) and observational studies (preprint; no information provided on included studies), suggesting that all masks as well as N95 respirators were associated with a reduction of risks (moderate and low certainty, respectively). However, the risk reduction associated with surgical masks and non-medical masks was not statistically significant (34):

- all masks – RR 0.47; 95% CI 0.28 to 0.81; p=0.006 (GRADE moderate; 5 comparisons)
- N95 or equivalent – RR 0.42; 95% CI 0.21 to 0.87; p=0.014 (GRADE low, 4 comparisons)
- medical or surgical masks – RR 0.71; 95% CI 0.28 to 1.80; p=0.471 (GRADE very low; 2 comparisons)
- non-medical masks – RR 0.68; 95% CI 0.21 to 2.23; p=0.520 (GRADE very low; 2 comparisons)

This review found similar findings (greater efficacy of N95 or equivalent over surgical masks) for SARS/MERS infection, and for combined coronavirus infections (SARS, MERS and SARS-CoV-2) (34):

- N95 or equivalent – RR 0.37; 95% CI 0.24 to 0.55; p<0.001 (GRADE low, 13 comparisons)
- medical or surgical masks – RR 0.75; 95% CI 0.46 to 1.22; p=0.247 (GRADE very low; 9 comparisons)
- non-medical masks – RR 0.74; 95% CI 0.26 to 2.12; p=0.575 (GRADE very low; 2 comparisons)

However, all were based on observational studies and GRADEd as low or very low confidence. The only RCT evidence with high GRADE scores were for influenza, which did not show any difference between N95 respirators and surgical masks (34).

By setting – healthcare

Chou and others included evidence from healthcare settings, although there was too little evidence to draw conclusions based on COVID-19 evidence only (33). In considering wider evidence from SARS-CoV-1 and MERS, the review suggested that N95 respirators might be more effective than surgical masks in reducing risk of infection in healthcare settings, however it was of low-strength evidence, with the majority of studies from high risk settings including intensive care or frequent aerosol generating procedure (AGP) exposure. In their network meta-analysis, Kim and others (preprint; no information provided on included studies) found that, in healthcare settings, the use of N95 respirators was associated with a reduction of risks, but not surgical masks (including evidence from all coronavirus outbreaks, and comparing to no masks or very low frequency of use) although the certainty of these findings was reported to be low or very low (34):

- N95 or equivalent – RR 0.39; 95% CI 0.26 to 0.58 (GRADE low, 4 studies)
- surgical masks – RR 0.81; 95% CI 0.48 to 1.38 (GRADE very low; 2 studies)

Tian and others conducted a meta-analysis to assess the effectiveness of different types of face coverings in healthcare settings, considering a wider range of respiratory viruses (see Evidence table 3 for results). Sub-group analysis for COVID-19 suggests that both N95 respirators and surgical masks were effective in reducing infection risk, although this was based on a small number of studies (35):

- N95 respirator (vs no N95) – OR 0.08; 95% CI 0.01 to 0.65 (3 studies)
- surgical masks (vs no surgical mask) – OR 0.02; 95% CI 0.00 to 0.37 (one study)

Other PPE assessed in this review included face protection (mainly goggles and face shield), gloves and gowns. All were effective in reducing infection risk when considering all viral respiratory epidemics but no results were statistically significant when considering COVID-19 only. This review suggests that frontline healthcare workers were at higher risk of infection for all viral respiratory epidemics, but the results were not significant if considering COVID-19 only (10 studies). Similarly, healthcare workers participating in aerosol generating procedure were at higher risk of respiratory infections than those not participating in these procedures, but this was not significant when considering COVID-19 only (3 studies) (35).

A SAGE paper published in April 2021 considered the use of face coverings in healthcare settings to mitigate airborne transmission of SARS-CoV-2, suggesting that to reduce transmission risk through aerosols, surgical masks (type II fluid resistant) should be used as source control by both patients and staff, and that attention should be given to ventilation (reported with medium confidence) (40). This paper points out that there was variation in hospital-acquired SARS-CoV-2 infections but that it was not possible to identify whether such variations could be related to FFP3/N95 use (reported with high confidence) (40).

Whilst the evidence suggests that N95 respirators might be effective in reducing infection risks in healthcare settings, the results are less clear for surgical masks. Factors that might impact these results (including when comparing results between respiratory viruses) include i) the uncertainty related to the airborne transmission of SARS-CoV-2 and the ability of face coverings to block small aerosols; ii) the peak of infectiousness of COVID-19 (which is believed to be around symptom onset) might be more likely to happen when patients are in community settings rather than in healthcare settings; and iii) a change of face coverings use in healthcare settings where universal masking has been widely implemented since the start of the COVID-19 pandemic (but was not common practice before).

By setting – community

The evidence identified suggests that the use of face coverings within the community is effective in helping to reduce transmission of SARS-CoV-2 (33, 36). The evidence on the effectiveness of specific types of face coverings (compared to no face covering) is less clear, although surgical masks were associated with a decreased risk of SARS-CoV-2 infection (33). For non-medical masks, the review by Chou and others concluded that there was too little evidence to draw conclusions as only one study (case-control) had been identified (33) while the ECRI review concluded based on this case-control study and indirect evidence from laboratory studies that non-medical masks might reduce transmission of SARS-CoV-2 (37).

The evidence summary by the Alberta Health Service was conducted in the context of the emergence of new variants to assess which techniques would make face coverings more effective in reducing the transmission of these new variants. However, no specific evidence on new variants and face coverings effectiveness was identified (38).

A SAGE-EMG paper published in January 2021 discussed the evidence on the role of physical distancing and fabric face coverings in community settings in mitigating the Alpha variant (B.1.1.7) (1). No specific evidence on the effectiveness of face coverings in the context of the Alpha variant was identified. Following a precautionary approach based on the higher transmissibility of this variant, the authors concluded (with high confidence) that physical distancing and fabric face coverings were important mitigation strategies and were likely to be needed to be applied more consistently and more effectively to be able to mitigate the transmission of the Alpha variant.

Table 1. Summary table – effectiveness of face coverings (COVID-19 evidence only)

Review	Face covering versus no face covering	N95/surgical masks versus non-medical masks	Different types of non-medical masks (or material)	Additional considerations
Community settings				
PHE, 2021 (36)	• Use of face coverings in community may be effective in reducing transmission when a face coverings policy is in place (population- and individual-level studies)	• N95 performed better than non-medical mask (laboratory studies) • Non-medical masks made of 2- or 3-layers can have similar filtering efficiency than surgical masks (laboratory studies)	• All face coverings deemed to offer some level of protection (laboratory studies) • Combining multiple layers of different materials seemed to improve filtration efficiency (laboratory studies)	• Mask fit considered an important determinant of filtration efficiency (laboratory studies) • Repeated washing and wearing could reduce filtration efficiency but this depends on the material (laboratory studies)
Chou and others, 2021 (28 to 33)	• Any mask (versus no mask): decreased risk of infection (low strength of evidence; one RCT and 3 observational studies) • Surgical mask (versus no mask): decreased risk of infection (low strength of evidence; one RCT and one observational study) • Non-medical mask (versus no mask): too little evidence to draw conclusion (one observational study)			• No serious harms reported for face covering use. Reporting of harms suboptimal. When reported, most common adverse effects were discomfort, breathing difficulties and skin events.

Review	Face covering versus no face covering	N95/surgical masks versus non-medical masks	Different types of non-medical masks (or material)	Additional considerations
Alberta Health Services, 2021 (38)		• N95 have the highest filtration efficiency, followed by surgical masks and then non-medical masks (laboratory studies) • Optimised non-medical masks might have similar efficiency than surgical masks (limited evidence)	• Non-medical masks should be made of 3 layers.	• Face covering should be well-fitted to reduce leakage • Fit modification methods such as mask knotting and tucking, nylon hosiery overlays or mask braces might be associated with increased efficiency • In one laboratory study, particle exposure was reduced at similar rates when either source or receiver used double masking or fit modification. Exposure was further reduced when measures used by both.
ECRI, 2021 (37)	• Non-medical masks might reduce transmission of SARS-CoV-2 (laboratory studies and one observational study)		• High density woven cotton and multilayer woven textile combinations seem to be appropriate materials for face coverings (laboratory studies) • Disposable paper (or paper-like filter inserts) and double-	

Review	Face covering versus no face covering	N95/surgical masks versus non-medical masks	Different types of non-medical masks (or material)	Additional considerations
			masking increase protection (laboratory studies)	
Healthcare settings				
Chou and others, 2021 (28 to 33)	• Any mask (versus no mask): too little evidence to draw conclusion (2 observational studies) • N95 (vs no mask): too little evidence to draw conclusion (3 observational studies) • Surgical mask (versus no mask): too little evidence to draw conclusion (3 observational studies)			• Consistent use (versus inconsistent): too little evidence to draw conclusion (one observational study) • No serious harms reported for face covering use. Reporting of harms suboptimal. When reported, most common adverse effects were discomfort, breathing difficulties and skin events.
Tian and others, 2021 (35)	• Surgical mask (vs no surgical mask): OR 0.02, 95% CI 0.00-0.37 (one study) • N95 (vs no N95): OR 0.08, 95% CI 0.01-0.65), p=0.02 (3 studies)			• Infection prevention and control practices (IPAC) training (vs no training): OR 0.21, 95% CI 0.07-0.61 (one study)

Results on face coverings use and behaviour

In addition to their mechanical ability to filter particles, factors such as mask fitting or consistency of use might impact the effectiveness of face coverings. Differences in how face coverings are used might also impact on effectiveness, among other reasons due to the fact that healthcare professionals have been trained in how to securely use PPE while the general public is not. It should also be noted that guidance and recommendations assume good compliance with PPE procedures such as donning and doffing, while this is not always the case, even in healthcare settings.

Consistency of use

Chou and others aimed at assessing the impact of consistent use of face coverings in healthcare settings (compared to inconsistent use), but the evidence on the COVID-19 pandemic was limited to one observational study (33).This study suggested that always wearing N95 or always wearing surgical masks were associated with a risk reduction compared to less consistent use of N95 or surgical masks. Consistent use of either surgical mask or N95 was shown to have reduced infection risk for SARS-CoV-1 and MERS, albeit in a small number of studies with low quality evidence (33).

Kim and others (preprint; no information provided on included studies) reported a risk reduction of respiratory viral infection when there was a high adherence to face covering use compared to low adherence (RR 0.45; 95% CI 0.24 to 0.85). This meta-analysis, based on 4 studies, is based on evidence from various respiratory viruses and it is unclear whether it included studies from the COVID-19 pandemic (34).

Fitting and cleaning

Laboratory studies suggested that mask fit was an important determinant of filtration efficiency of face coverings and that face coverings should be well-fitted to reduce leakage (36, 38). Fit modification methods such as mask knotting and tucking, nylon hosiery overlays or mask braces might be associated with increased efficiency, although more studies are needed to be able to recommend specific modification (38). The double-masking discussed in the previous section can also be seen as a technique to optimise the fit of surgical masks (38).

Fit modification through knotting, tucking or double masking were both shown to reduce particle exposure when worn by either the source or receiver, although the greatest reduction was seen when used by both (38).

Laboratory studies suggest that repeated washing and wearing could reduce filtration efficiency (36), but more studies are needed to assess how different materials and different types of face coverings are impacted. It is acknowledged that mask disinfection methods (other than thermal) can be used (especially chemical and radiation) (41), but that this was not the focus of this paper.

Donning and doffing procedures and related training

Tian and others found that in healthcare settings infection prevention and control practices (IPAC) training were associated with a large reduction in infection risk when considering evidence from both SARS and COVID-19 pandemics (OR 0.24; 95 CI% 0.14-0.42, p<0.001; 17.1% risk reduction; moderate certainty, 6 studies). Of these 6 studies, only one was specific to COVID-19, which also suggested that IPAC training significantly reduced infection risk (OR 0.21; 95% CI 0.07-0.61) (35).

The SAGE paper on face coverings and healthcare settings noted the importance of implementing effective use of respiratory protection equipment (FFP3 and N95), including training, as a component of risk management system (reported with medium confidence) (40).

However, whilst it is widely accepted that adequate donning and doffing procedures of PPE contribute to reducing infection risk in healthcare workers (42, 43), no review-level evidence specific to COVID-19 was identified. Such procedures were mainly developed to protect from droplet transmission and it is unclear how they translate to airborne transmission.

Apart from a cross-sectional study from Singapore identified by Bakhit and others (39) that showed that only 12% of the sample (general public) wore N95 respirators correctly, there is a lack of evidence on donning and doffing procedures in non-healthcare settings. It is unclear how face coverings are put on and removed by non-trained individuals in the community and how it can impact face covering effectiveness, including in relation to mask fitting. The SAGE-EMG paper on fabric face coverings and new variants also noted (reported with medium confidence) that public health advice on face coverings should be strengthened to promote their correct wearing and good hygiene practices as well as to provide clear advice on selection of effective face coverings (1).

Negative effects of face covering use

In the systematic review by Bakhit and others, most of the included studies reported on discomfort and irritation outcomes but no studies reported on mask contamination or risk of compensation behaviour (that is, risk of non-adherence to other measures when using face masks) (39).

Conclusions

Overall, the evidence suggests that all face coverings are, to some extent, effective in reducing transmission of SARS-CoV-2 in both healthcare and community settings. N95 respirators are likely to be the most effective, followed by surgical masks and then non-medical masks, although optimised non-medical masks made of 2 or 3 layers might have similar efficiency than surgical masks. However, this is based on a heterogenous body of evidence (different settings, different study designs, and so on) that does not necessarily take into account real-world conditions (donning and doffing, consistency of use, and so on) or differences in transmission risks (peak of infectivity, community vs healthcare settings, and so on). The evidence specific to

COVID-19 is still limited and does not allow firm conclusions to be drawn by settings or type of face covering.

Wider evidence from other respiratory viruses suggests that, in healthcare settings, N95 respirators might be more effective than surgical masks in reducing the infection risk.

Evidence mainly based on laboratory studies suggest that all face coverings provide some protection for both droplets and aerosols and that face coverings should be well-fitted to increase effectiveness. However, more research is needed to assess the effectiveness of specific types of face coverings (including double masking) in relation to aerosol filtration and face seal leakage in real-world conditions (rather than in static laboratory conditions). This would have practical consequences for public health advice on which types of face covering should be worn in settings at increased risk of airborne transmission, such as in poorly ventilated indoor settings.

There is a need for improved training (in healthcare settings) and public health messaging (in community settings) on mask fitting and adequate use of PPE. More research is needed to improve knowledge on how face coverings are used by different population subgroups and in different community settings, and on how this could impact on effectiveness. Similarly, more research is needed to assess the effectiveness of donning and doffing procedures in relation to airborne transmission and fomite transmission in healthcare settings.

Wider evidence from other respiratory viruses showed that the risk of respiratory infection was reduced when face coverings were consistently used, but more evidence is needed to assess how this translates specifically to the COVID-19 pandemic and to different settings. This is specifically relevant to indoor settings where risk of airborne transmission might be greater.

No evidence on the effectiveness of face coverings against specific variants of SARS-CoV-2 was identified and there is a need for higher quality studies to assess the effectiveness of different types of face coverings in real-world settings, and especially in community settings.

Limitations

As this overview of the evidence is based on review-level evidence, it is dependent on the quality and reporting of those reviews. Most of the reviews have not formally GRADEd the evidence, lacked assessments of risk of bias of included studies and were not peer-reviewed.

Most of the primary studies included in the reviews were at risk of bias due to study design considerations. Some of the primary studies were preprints manuscripts. Preprints have not been peer reviewed nor subject to publishing standards and may be subject to change.

The evidence was heterogeneous in terms of methods, settings and study designs. Additionally, there was often not enough information provided in relation to settings and type of face coverings used.

This paper mainly relies on evidence from the COVID-19 pandemic and did not consider wider evidence except to highlight specific points from systematic reviews that conducted meta-analyses or graded the evidence based on other respiratory viruses.

Knowledge gaps

More research is needed to improve knowledge on the viability and infectivity of SARS-CoV-2 in short and long-range respiratory aerosols and to determine the overall contribution of airborne transmission to the COVID-19 pandemic. This includes methods to sample and culture virus from the environment over a range of particle sizes.

More research is also needed to assess the impact of environmental factors (such as temperature and humidity) on aerosol viability in conditions that are realistic for indoor environments.

More research is needed to assess the dose-response for SARS-CoV-2 in respiratory particles, how and when these are generated by individuals infected with the virus, and when the peak of infectivity occurs for aerosol generation. There is a need for higher quality studies to determine airborne transmission risk and impact of mitigations in real-life settings.

More research is needed to assess the effectiveness of different types of face coverings in different settings, both in community (surgical masks versus non-medical masks) and healthcare settings (surgical masks versus N95 or equivalent), particularly from well-designed and powered intervention studies (including RCTs where appropriate).

In particular, there is an urgent need to assess the effectiveness of different types of face coverings (including double masking) in relation to aerosol filtration and face seal leakage under typical wearing conditions (rather than static lab tests), and their ability to reduce risk of airborne, droplet and fomite transmission. As mask fit is the most important determinant of the performance of a respirator, real-world studies are needed to confirm results of mask fit-testing and to assess the impact of mask fitting on protection against aerosols. In design of filtering face masks for protection against infectious agents, source control is of similar importance to personal protection. This research will have practical consequences for public health advice on which types of masks should be worn in settings at increased risk of airborne transmission.

Whilst it is out of the scope of this review to consider other PPE elements including eye protection, there is also a need for higher quality evidence on any additive protection to the nose and mouth through other elements such as face shields (often worn without face coverings with unknown efficacy), worn in combination with a mask.

More research is needed to improve knowledge on how face coverings are used by different population subgroups and in different community settings, and how this could impact on effectiveness. Similarly, more research is needed to assess the effectiveness of donning and doffing procedures in relation to airborne and fomite transmission in healthcare settings.

Evidence tables

Evidence table 1. Airborne transmission of SARS-CoV-2 virus

Reference	Review question	Evidence	Key findings
Heneghan and others, 2021 (19) Preprint (peer-review status on 24 March 2021: approved with reservation by one reviewer and not approved by 2 other reviewers.) **AMSTAR 2 rating**: moderate	**Review question:** to identify, appraise and summarise the evidence from studies of the role of airborne transmission of SARS-CoV-2. **Virus type**: only SARS-CoV-2 for primary studies.	**Search dates:** from 1 February 2020 to 20 December 2020 **Studies included** • Total =89 (22 reviews and 67 primary studies) **Reviews** • Total = 22 (5 systematic reviews and 17 non-systematic reviews) • 10 reviews included only evidence on SARS-CoV-2 and 12 included evidence on SARC-CoV-2 and SARS-CoV-1, MERS or Influenza type illness • Outcomes: airborne transmission (n=16); airborne transmission and procedures (n=3); air ventilation, filtration and recirculation (n=3) **Primary studies** • Total = 67 (all study designs were considered, inclusion criteria was they	**Overall results** • Of the 42 studies that reported binary RT-PCR tests, 24 (57%) reported positive results for SARS-CoV-2 (142 positives out of 1,403 samples: average 10.1%, range 0% to 100%). • Of the 10 studies that performed viral culture, 7 could not isolate SARS-CoV-2 virus and did not observe cytopathic effect. The 3 studies that detected viable virus were conducted in hospital settings (patient rooms). • Based on the overall body of evidence, SARs-CoV-2 RNA can be detected in the air in both community and hospital settings (indoor and outdoor). However, there is a lack of recovered viral culture samples. Many factors for example humidity, temperature, can affect the infectivity of airborne viruses.

Reference	Review question	Evidence	Key findings
		should include sampling for SARS-CoV-2 detection) **Settings** • Healthcare settings: n = 50 – Include: hospitals (n=50), outdoor (n=2), indoor (n=47), student healthcare centre (n=1) • Community settings (indoors and outdoors): n = 17 – Include: bus (n=4); restaurant (n=2); block of flats (n=2); choir practice (n=2); meat processing plant (n=1); home residence (n=1); quarantine hotel (n=1); quarantined household (n=1); care home (n=1) **Overlap between reviews** • Of the 67 included primary studies, 22 were unique studies (not included in the other reviews considered for this summary)	**Outdoor and community transmission** • 7 studies conducted RT-PCR air sampling, of which 2 studies reported weak positive RNA samples for 2 or more genes (5 of 125 samples positive: average 4.0%). **Healthcare setting transmission** • Out of the 50 studies conducted in a healthcare setting, 42 conducted RT-PCR air sampling, with 24 reporting positive samples. • No association between hospital setting type and RT-PCR detection was observed. **Limitations** • Current evidence on airborne transmission is weak. • All primary studies were assessed to be of low quality, and none were comparable. • Outcome ascertainment for the detection of viable SARS-CoV-2 virus was limited due to a high heterogeneity of study characteristics and experimental design (including PPE, patient activities, detection methods, standardisation methods, sampling distances and air movement).

Reference	Review question	Evidence	Key findings
			• The presentation of the evidence does not allow for conclusions to be drawn according to study design or setting.
Public Health Agency Canada (PHAC), 2020; 2 versions: • Original, 2020 (20) • Update, 2021 (21) Not peer-reviewed **AMSTAR 2 rating (20)**: low **AMSTAR 2 rating (21)**: critically low (downgraded due to lack of discussion on quality and risk of bias when discussing results)	**Review question:** to summarize studies providing evidence of potential SARS-CoV-2 aerosol transmission **Virus type**: only SARS-CoV-2 for primary studies.	Original review (20) **Search dates:** up to 6 November 2020 **Studies included** • Total =58 • Primary studies (n=57); systematic review and meta-analysis (preprint) (n=1) **Study design** • Outbreak investigations (n=15), laboratory animal experiments (n=4), SARS-CoV-2 viability experiments (n=4), air sampling (n=17), expelled breath (n=3), modelling (n=1) and fluid dynamics (n=21) **Settings** (outbreak investigations) • Bus (n=1), restaurant (n=2), choir practice (n=2), cruise ship (n=2), meat processing plant (n=1) Update (21) **Search date:** up to 12 March 2021 **Studies included** • Total = 46 new primary studies	Original review (20) • Outbreak and cluster investigations suggest aerosol transmission of SARS-CoV-2 may have occurred in some settings. The potential for aerosol transmission appears to be greater in poorly ventilated crowded indoor spaces and when index and secondary cases where in the same space for extended period of time. • Experimental evidence indicates that viable (infectious) SARS-CoV-2 can remain suspended in air for prolonged periods (between 3 and 16 hours) in artificially created aerosols. Two studies detected viable SARS-CoV-2 virus in hospital settings (patient rooms). • Exhaled breath and air sampling studies show that SARS-CoV-2 viral RNA can be detected from the environment, however, this was based on low sample size and there was heterogeneity between studies. • Indirect evidence from modelling studies suggests that SARS-CoV-2 virus can be dispersed beyond 2 metres and can remain

Reference	Review question	Evidence	Key findings
		Study design • Outbreak investigations (n=12), environmental sampling (n=28), animal studies (n=2), expelled breath biological studies (n=3) and SARS-CoV-2 viability experiment study (n=1); fluid dynamic simulations excluded from this update. **Settings** (outbreak investigations) • Quarantine hotel, nursing home, hospital, bus, restaurant, sport facilities, department store and apartment building **Overlap between reviews** • The original review contains 32 unique studies and the update 17 (not included in the other reviews considered for this summary)	suspended for extended periods of time. In particular, fluid dynamics evidence suggests that smaller particles can remain suspended in the air for longer and travel greater distances. Air currents could increase dispersion and lack of ventilation could lead to accumulation of infectious particles. Temperature and humidity also impact particle sizes and flow. • The amount of viral particles in respiratory particle depends on the viral load of the infected person but the quantity of respiratory particles expelled varies between individuals and depends on the activity (for example breathing, coughing, speaking or singing). The amount of SARS-CoV-2 necessary to cause infection has not been established. • The impacts of other environmental factors such as temperature and humidity on aerosol transmission are not well understood. New findings from update (21) • The 12 new outbreak investigations add to the evidence that, at least in some of these outbreaks, 1) mask use was reported to have

Reference	Review question	Evidence	Key findings
			been infrequent or not adequate (although mask used was not always described) and 2) primary cases were likely to have been pre-symptomatic or in the early stage of infection. The new studies also suggest that in some cases individuals were engaged in physically exertive activities such as singing or exercise classes at the time of transmission. • The 28 new biological monitoring studies (environmental sampling conducted in both healthcare and community settings) add to the evidence that 1) in 2 studies conducted in hospital settings, viral RNA had been detected on no touch surface, 2) viable virus had been detected in air samples collected from a car in which a mildly symptomatic individual was present and 3) in a study comparing hospital rooms and household with active cases, the household environmental air was 8 times more likely to be contaminated with viral RNA (OR 8.75; 95% CI 1.21-63.43; $p=0.058$) and that this might have be due to differences in air exchanges and ventilation. • The new viability experimental study reported that virus infectiousness and decay rates in aerosols were highly dependent on the following environmental conditions, by order

Reference	Review question	Evidence	Key findings
			of influence: sunlight exposure levels, temperature and humidity. • In the few studies in which viable virus was detected, the environmental samples had been collected near the infected individual (<2 metres).

Evidence table 2. Variants of concern

Reference	Review question	Evidence	Key findings
Curran and others, 2021 (SPOR Evidence Alliance and COVID-END) (23) Not peer-reviewed **AMSTAR 2 rating:** critically low	**Review question:** to determine the transmissibility of the 3 major variants of concern (B.1.1.7, B.1.351 and P.1) and the reasons attributed to their increased transmissibility. **Variants of concern**: B.1.1.7 (Alpha), B.1.351 (Beta), P.1 (Gamma)	**Search dates**: up to 21 February 2021 (1 March 2021 for grey literature) **Study design** • Reviews, animal studies and studies that only predicted modelling data was excluded. **Studies included** • Total = 23 • Preprint (n=13), grey literature (n=7), peer-reviewed (n=3) **Settings** • UK (n=13), United States (n=3), Brazil (n=2), Israel (n=1), Wales (n=1), Zambia (n=1), multiple countries (n=2) **No. of primary studies / variants of concern** • P.1 (n=3), B.1.351 (n=3), B.1.1.7 (n=20) **Overlap between reviews** • Of the 23 included studies, 12 were unique (not included in the other reviews considered for this summary). All 3 included studies for the B.1.351 variant were unique; 2 out of 3 included studies for the P.1 variant were unique.	**Increased transmissibility (B.1.1.7)** • Studies reported an increase in the incidence of B.1.1.7 compared to other variants. • Transmission risk for the B.1.1.7 variant ranged from 45 to 71% higher. • Two studies reported an increase in the R0 compared to non-VOC, ranging from 75 to 78% higher. • Six studies reported an increase in the Rt, ranging from 1.1 to 2.18. **Increased transmissibility (B.1.351)** • One study reported an increase in transmissibility for B.1.351 (Rt = 1.55; 95% CI 1.43 to 1.69; weekly rate relative advantage ratio =1.58; 95% CI 1.45 to 1.72) but no conclusion can be drawn (evidence too limited) **Increased transmissibility (P.1)** • Two studies (Brazil) reported an increase in transmissibility for P.1, but no conclusion can be drawn (evidence too limited)

Reference	Review question	Evidence	Key findings
			Viral Load • For the B.1.1.7, P.1 and B.1351 variants, evidence suggests that there may be an increase in viral load using RT-PCR Ct values as a proxy measure. • For the B.1.1.7 variant, SGFT positive samples had higher inferred viral loads compared to other gene targets. • A three-fold higher viral load was observed in the 501Y variant (B.1.1.7) compared with wild type. **Infectious period** • B.1.17 may cause prolonged infection (13.3 days vs 8.2 days) with consistent peak Ct values, compared to non B.1.1.7. A prolonged infectious period may be a contributory factor to SARS-CoV-2's increased transmissibility.
Public Health Ontario. 2021 (24) Not peer-reviewed	**Review question:** to summarise what is known about the B.1.1.7 variant and factors attributed to its increased transmissibility.	**Search dates**: up to 15 February 2021 **Studies included** • Total = 68 (majority preprints) **Outcomes** • Transmissibility: n = 25 (16 preprints, 6 governmental publications)	**Increased incidence and transmissibility** • 25 included studies reported on transmissibility of the B.1.1.7 variant. The majority suggest a relatively higher transmissibility, compared to other lineages.

Reference	Review question	Evidence	Key findings
AMSTAR 2 rating: critically low	**Variant of concern**: B.1.1.7 (Alpha)	**Overlap between reviews** • Of the 68 included studies, 12 were unique (not included in the review by Curran and others).	• One government report and 2 preprints documented a rapid rise in COVID-19 incidence with B.1.1.7. • Modelling studies from the UK, US and Canada estimated higher transmissibility. **Changes in reproduction number and growth rate** • Six studies and 2 government documents report a higher Rt for the B.1.1.7 variant, with values ranging from 1.17–1.72. **Viral Load** • Three studies (2 preprints, one peer reviewed), reported inconsistent results. A causative association between viral load and B.1.1.7 was not examined. **Secondary attack rates** • Findings from 2 studies in the UK (retrospective matched cohort study and a genomic sequencing study) suggest that B.1.1.7 is associated with higher secondary attack rates compared to non-B.1.1.7 (Cohort study: 15.1% and 9.8% respectively), (Sequencing study: 12.9% and 9.7% respectively).

Reference	Review question	Evidence	Key findings
			Disease severity • Findings from 6 studies in the UK, suggest an increased risk of hospitalisation and mortality associated with B.1.1.7. • Study limitations and non-comparability of included modelling studies weaken the strength of this evidence. **Vaccine effectiveness** • Findings from 10 reports (one vaccine efficacy trial, 9 pre-print in vitro neutralization assays), suggest that the B.1.1.7 variant does not significantly impact vaccine effectiveness.
Public Health Ontario. 2021 (25) Not peer-reviewed **AMSTAR 2 rating**: critically low	**Review question: to** summarise what is known about the B.1.351 variant and factors attributed to its increased transmissibility. **Variant of concern**: B.1.351 (Beta)	**Search dates**: up to 4 February 2021 **Studies included** • Not reported. **Overlap between reviews** • All the included studies were unique (not included in the review by Curran and others).	**Impact on detection methods** • There is no evidence that B.1.351 affects RT-PCR assays – 2 studies reported minimal effects of B.1.351 mutations. **Increased risk of infection** • Findings suggest that B.1.351 mutations may reduce the efficacy of 3 classes of therapeutically relevant monoclonal antibodies and neutralising antibodies in COVID-19 convalescent plasma.

Reference	Review question	Evidence	Key findings
			Vaccine-induced antibodies • Findings demonstrate that vaccine-induced antibodies have a reduced neutralising ability against B.1.351 mutations. **Transmissibility** • One modelling study from South Africa estimated that the B.1351 variant had a 50% higher transmissibility than previously circulating lineages.
Public Health Ontario. 2021 (26) Not peer-reviewed **AMSTAR 2 rating**: critically low	**Review question:** to summarise what is known about the P.1 variant and factors attributed to its increased transmissibility. **Variant of concern**: P.1 (Gamma)	**Search dates**: up to 14 January 2021 **Studies included** • Not reported. **Overlap between reviews** • Only one of the included studies was included in the review by Curran and others.	**Transmissibility** • One study suggests a higher transmissibility of the P.1 variant based on an increased prevalence (42%, 13 out of 31) of P.1 samples, within a cluster of SARS-CoV-2 cases in Brazil. **Immunity and reinfection** • Findings from 2 reports suggest a possibility of reinfection with P.1. Findings are based on a resurgence of SARS-CoV-2 cases in an area of Brazil with highly documented seroprevalence, and one confirmed case of P.1 reinfection in Brazil.

Reference	Review question	Evidence	Key findings
			Vaccine effectiveness • Two studies reported findings that suggest a diminished neutralizing activity against the E484K mutation that is present in the P.1 variant. • No research on the impact of the P.1 variant on disease severity and on diagnostic assays was identified.

Evidence table 3. Face coverings

Reference	Review question	Evidence	Key findings
Alberta Health Services, 2021 (38) Not peer-reviewed **AMSTAR 2 rating**: critically low	**Review question:** in the community setting where non-medical masks are used, what is the evidence for the use of 2 non-medical masks (or non-medical masks with multiple layers) to prevent COVID-19 transmission? Are there ways to optimize fit to improve filterability and reduce transmission? **Settings**: community **Mask types**: non-medical masks	**Search dates**: 1946 up to 22 February 2021 **Study design** • not specified **Studies included** • Only guidelines and laboratory studies identified (n=10) **Overlap between reviews** • Of the 10 included studies, 3 were unique studies (not included in the other reviews considered for this summary)	• Laboratory studies suggest that N95 respirators have the highest filtration efficiency, followed by surgical masks and then cloth masks. • Based on limited evidence, optimised cloth masks might have similar efficiency than surgical masks, and non-fitted N95 respirators might have poor filtration efficiency. • Cloth masks should be made of 3 layers. • Mask should be well-fitted to reduce leakage. Fit modification methods such as mask knotting and tucking, nylon hosiery overlays or mask braces might be associated with increased efficiency through improved fitting. However, more studies are needed to be able to make specific mask recommendations. • Based on one laboratory study, double-masking (with one medical mask and one non-medical mask) was associated with a reduction in exposure to particles. • The same laboratory study showed that particle exposure was reduced at similar rates when either the source or receiver used double or fit-modified masks, but that

Reference	Review question	Evidence	Key findings
			exposure was further reduced if these measures were used both source and receiver. • No studies have examined double masking with 2 non-medical masks. However, using one single mask made of multi layers might have similar efficiency . Double masking using 2 medical masks should be discouraged as it would not improve fit. • No published data suggested that the new variants are more readily transmitted when good masking practice and hand hygiene were used. • The body of evidence was deemed as being limited and a lack of clinical data was noted. Other limitation was heterogeneity between studies.
Bakhit and others, 2021 (39) Externally peer-reviewed	**Review questions** Q1. What factors are associated with adherence to, or misuse of face masks? Q2. What are the psychological and	**Search dates:** inception to 18 May 2020 **Study design** • experimental (RCT) and observational (any design); preprints probably not included (not specified)	**Key findings of relevance on face covering use and behaviour** • Adherence to mask use was higher in the surgical face mask group compared to the N95 mask group (4 studies – all non-COVID-19, n=7,960 participants) – OR 1.26, 95% CI 1.08 to 1.46, p<0.01, I2=27%

Reference	Review question	Evidence	Key findings
AMSTAR 2 rating: high	physiological impacts of face mask use? Q3. What is the risk of face mask contamination? **Settings:** community and healthcare **Context:** virus (any type) and non-virus transmission in relation to airborne contaminants (such as gas or dust) **Mask types:** surgical masks, N95 mask, non-medical masks	**Studies included** • Total =37 studies (but only 2 from the COVID-19 pandemic) **By study design** • 12 cluster-RCT, 9 surveys, 3 RCT, 4 multiple cross-over, 2 single-arm, one prevalence, one before-after, one direct observational, one lab-based, one randomised cross-over, one cross-over, one unclear **By outcome** • 20 studies (8 RCT, 7 survey, one before-after, one direct observation, one lab-based, 2 multiple cross-over) reported on discomfort and irritation • 17 (14 RCT, 3 observational) studies reported on adherence to face mask use, of which, 11 were included for meta-analysis • 6 studies (4 RCT, 2 observational) reported on psychological impacts of face masks • 4 studies (2 lab-based, one randomised cross-over, one cross-over) reported on physiological effects of masks and shortness of breath	• In healthcare settings, types of face mask misuse included frequent touching of the face or mask and wearing the mask below the nose (no COVID-19 studies identified). • In community settings, one cross-sectional study (COVID-19) reported that only 90 out of 714 (12%) of participants wearing N95 passed a visual mask fit test. • Discomfort and irritation associated with mask use was reported by 20 studies in community and healthcare settings (including one COVID-19 study) and was reported to increase with duration of use and varied by mask type. Headaches, facial itching, skin irritation and difficulty breathing were among reported symptoms. • No evidence identified for risk of mask contamination. • No evidence identified for risk compensation behaviour (non-adherence to other precautions when using face masks). • Overall, there was insufficient evidence to evaluate adverse effects of face mask use and factors associated with their misuse.

Reference	Review question	Evidence	Key findings
		Meta-analysis • Outcomes calculated as odds ratios (OR) and risk difference (RD) (95% CI) • Random effects model used to address heterogeneity (measured with I2) • Subgroup analysis for adherence to mask use **Overlap between reviews** • All 37 studies included in this review were unique studies (not included in the other reviews considered for this summary).	• Several studies had a high risk of reporting and detection bias.
Chou and others, 2021 Living review: 6 versions published: the original (28) and 5 updates (29 to 33) **AMSTAR 2 rating:** high	**Review question:** to examine the effectiveness of N95, surgical, and cloth masks in community and health care settings for preventing respiratory virus infections, and effects of reuse or extended use of N95. **Settings:** healthcare and community	**Search dates**: 2003 up to 2 February 2021 (update 5) **Study design** • Randomised trials, cohort, case-control and cross-sectional studies (preprints were included in the original review but not in the updates) **Studies included** • In original review (30), 39 studies: – 18 RCTs – 10 cohorts – 11 case-control studies	**Key findings – respiratory viruses other than SARS-CoV-2** • Evidence on mask effectiveness stronger in healthcare settings than in community settings. • In healthcare settings, N95 might be more effective than surgical mask in reducing infection risk for SARS-CoV-1 but not for influenza (low strength of evidence, and studies mostly from high risk settings). • Consistent use of N95 or surgical masks may be associated with reduced risk of infection (SARS-CoV-1, MERS; low strength of evidence).

Reference	Review question	Evidence	Key findings
	Context: respiratory virus infection **Mask types:** all types included (N95, surgical and cloth masks)	• Of these, only 2 studies were direct evidence from the COVID-19 pandemic. • In updates (31 to 35), 10 additional studies identified, all COVID-19 • In total, 12 studies were direct evidence from the COVID-19 pandemic: – 8 from healthcare settings: o 5 cohorts o 2 case-control o one cross-sectional – 4 from community settings: o one RCT o one cohort o one case-control o one cross-sectional **Overlap between reviews** • Of the 4 included studies reporting on COVID-19 in community settings, 2 were unique studies (not included in the other reviews considered for this summary). The 8 studies on COVID-19 in healthcare settings were all unique as the other reviews focused on community settings. **Grading of evidence** • The strength of evidence was graded as high, moderate, low or insufficient based	**Key findings – SARS-CoV-2** Community settings: • Any mask (versus no mask): decreased risk of infection (low strength of evidence; one RCT and 3 observational studies) • Surgical mask (versus no mask): decreased risk of infection (low strength of evidence; one RCT and one observational study) • Cloth mask (versus no mask): too little evidence to draw conclusion (one observational study) Healthcare settings: • Any mask (versus no mask): too little evidence to draw conclusion (2 observational studies) • N95 (versus no mask): too little evidence to draw conclusion (3 observational studies) • Surgical mask (versus no mask): too little evidence to draw conclusion (3 observational studies) • N95 (versus surgical mask): too little evidence to draw conclusion (3 observational studies)

Reference	Review question	Evidence	Key findings
		on study design, risk of bias, inconsistency, indirectness and imprecision.	• Consistent use (versus inconsistent): too little evidence to draw conclusion (one observational study) **Harms** • No serious harms reported for mask use. • Reporting of harms suboptimal. When reported, most common adverse effects were discomfort, breathing difficulties and skin events.
ECRI, 2021 (37) Not peer-reviewed **AMSTAR 2 rating**: critically low	**Review question:** effectiveness of nonmedical cloth face masks worn by the public to reduce viral transmission and on considerations for textile materials and construction that may optimally protect against viral droplets. **Settings**: community **Mask types**: cloth masks (studies on N95 and medical-grade masks were excluded	**Search dates**: 1 January 2015 up to 16 February 2021 **Study design** • Clinical studies (including modelling and laboratory studies) **Studies included** • Total=44 primary studies (of which 24 were laboratory studies which were not extracted into evidence table) **Overlap between reviews** • Of the 44 included studies, 32 were unique studies (not included in the other reviews considered for this summary)	• One retrospective case-control study provide direct evidence on the use of non-medical cloth face masks, suggesting that they reduced COVID-19 transmission. This result was supported by other studies that provided indirect, low-quality evidence. • Based on findings from 24 laboratory studies: – high density woven cotton and multilayer woven textile combinations seem to be appropriate materials for face coverings – disposable paper (or paper-like filter inserts) and double-masking increase protection

Reference	Review question	Evidence	Key findings
PHE COVID-19 Rapid Evidence Service, 2021 (36) Externally peer-reviewed **AMSTAR 2 rating**: low	**Review questions:** Q1. What is the effectiveness of face coverings when used in the community? Q2. What is the efficacy of different types of face coverings for use in community settings? **Settings**: community **Context**: COVID-19 pandemic **Mask types**: all types included for question 1. For question 2, studies looking only at surgical mask and N95 were excluded.	**Search dates**: 1 January 2020 up to 22 September 2020 **Study design** • Experimental, observational and laboratory studies; modelling studies excluded **Studies included** • Total =31 studies (7 preprints) • For Q1: 17 observational studies (6 preprints), of which: – 12 ecological studies (population-level) – 3 individual-level studies: 2 retrospective cohorts, one case-control and 2 outbreak investigations – For Q2: 14 laboratory studies (one preprint) **Overlap between reviews** • Of the 31 included studies, 23 were unique studies (not included in the other reviews considered for this summary)	**Key findings for Q1** • Consistent evidence from population-level observational studies that policies mandating the use of face coverings in communities may be effective in reducing transmission of COVID-19. • Results from individual-level observational studies suggest that face masks may reduce transmission of COVID-19, both as wearer protection and as source control. However, this was based on a small number of studies in which other factors might have impacted the results. **Key findings for Q2** • All face covering material tested in the laboratory studies were deemed to offer some protection through filtration of respiratory particles compared with no barrier at all. Mouth-and-nose cover also reduced droplet spread from the wearer. • Different fabrics varied in their ability to filter droplets or aerosols of different sizes. • Mask fit was considered an important determinant of filtration efficiency. • Combining multiple layers of different materials seemed to improve filtration

Reference	Review question	Evidence	Key findings
			efficiency across the range of particle sizes and decreased the chance of large droplets produced by a cough being dispersed. • Repeated washing and wearing could reduce filtration efficiency but this was dependent on the type of material used. • Overall, studies identified were limited based on their design (only observational studies at risk of bias and residual confounding for Q1 and only laboratory studies for Q2), which limit the strength of the conclusions. Evidence was not graded.
Tian and others, 2021 (35) Accepted manuscript **AMSTAR 2 rating**: medium	**Review questions:** Q1. Which types of healthcare workers (HCWs) and which medical departments are at an increased risk of infection? **Q2**. Which infection prevention and control (IPC) practices are associated with	**Search dates**: 1946 up to 6 July 2020 **Study design** • Experimental (RCT) and observational (cohort, case-control, and cross-sectional studies) **Studies included** • Total = 54 studies (5 preprints) • By study design: 28 retrospective cohort, 10 case-control, 11 prospective cohort and 5 cross-sectional studies	**Key findings for Q1** • Infection rates in frontline HCWs vs non-frontline HCWs: – COVID-19: OR 1.34, 95 %CI 0.75 to 2.40, p=0.000; 10 studies. – all virus: OR 1.66, 95% CI 1.24 to 2.22, p=0.001 (4.4% risk difference); 32 studies; low certainty. • No statistical difference in infection risk between virus type (p=0.566). **Key findings for Q2**

Reference	Review question	Evidence	Key findings
	protective effects for infection in HCWs? **Q3**. Which exposures or procedures are associated with infection in HCWs? **Settings**: healthcare **Context**: viral respiratory pandemics (SARSCoV-2, MERS, SARS CoV-1, influenza A H1N1, influenza H5N1) **Mask types**: surgical masks and N95 respirators	• By virus type: 17 COVID-19, 18 H1N1, 15 SARS, 3 MERS and one H5N1. • 32 studies reported on infection rates in frontline HCWs • 27 studies reported on IPC, including 12 on surgical mask, 15 on N95 respirator and 11 on face protection • 5 studies reported on any face covering use and COVID-19 **Overlap between reviews** • Of the 5 studies reporting on face coverings and COVID-19, 3 were unique studies (not included in the other reviews considered for this summary). **Meta-analysis** • Random effects for continuous and dichotomous outcomes; subgroup analysis for each virus. • Inverse variance weighted meta-regression to assess association between study characteristics (co-variates) on relevant outcomes. • Not GRADEd for subgroups.	• Surgical mask vs no surgical mask: – COVID-19: OR 0.02, 95% CI 0.00 to 0.37; one study. – all virus: OR 0.37, 95% CI 0.20 to 0.66, p=0.000 (-11.9% risk difference); 12 studies; moderate certainty. • N95 vs no N95 respirator: – COVID-19: OR 0.08, 95% CI 0.01 to 0.65), p=0.02; 3 studies. – all virus: OR 0.32, 95% CI 0.19 to 0.52, p=0.010 (-4.4% risk difference); 15 studies; moderate certainty. • To note that: – definition and use of N95 varies across studies – N95 studies not always specified comparator – the 2 studies with strongest evidence for N95 respirators were both done during COVID-19 pandemic but settings not clearly defined (one prospective and one retrospective cohorts, both of poor quality). • Face protection vs no face protection: – COVID-19: OR 0.81, 95% CI 0.61 to 1.08; one study.

Reference	Review question	Evidence	Key findings
			– all virus: OR 0.41, 95% CI 0.27 to 0.62, p=0.009 (-10.6% risk difference); 11 studies; moderate certainty. • To note that the review does not provide definition of 'face protection'. Based on the studies included in the meta-analysis, it is likely to refer to goggles or face shield. • Gown and gloves both were effective in reducing respiratory virus infection risk, but in both cases not significant when considering only COVID-19 evidence. **Key findings for Q3** • Infection prevention and control practices (IPAC) training vs no training: – COVID-19: OR 0.21, 95% CI 0.07 to 0.61; one study. – all virus: OR 0.24, 95% CI 0.14 to 0.42, p<0.001 (-17.1% risk difference); 6 studies; moderate certainty. • Participation in intubation procedure vs no intubation procedure participation: – COVID-19: OR 2.72, 95% CI 1.27 to 5.82, p=0.429; 2 studies. – all virus: OR 4.72, 95% CI 2.71 to 8.24, p=0.045(-35.2% risk difference); 8 studies; moderate certainty.

Reference	Review question	Evidence	Key findings
			• Participation in aerosol generating procedure (including intubation) vs no participation: – COVID-19: OR 1.54, 95% CI 0.64 to 3.70, p=0.108; 3 studies. – all virus: OR 2.42, 95% CI 1.53 to 3.82, p<0.001 (-18.8% risk difference); 19 studies; moderate certainty.

References

1. SAGE-EMG. Application of physical distancing and fabric face coverings in mitigating the B117 variant SARS-CoV-2 virus in public, workplace and community settings January 2021 (viewed on 25 April 2021)
2. Milton DK. A Rosetta Stone for understanding infectious drops and aerosols Journal of the Pediatric Infectious Diseases Society 2020: volume 9, pages 413-415
3. World Health Organization (WHO). Transmission of SARS-CoV-2: implications for infection prevention precautions July 2020 (viewed on 25 April 2021)
4. Tang JW and others. COVID-19 has redefined airborne transmission British Medical Journal 2021: volume 373, pages 913
5. Bulfone TC and others. Outdoor Transmission of SARS-CoV-2 and Other Respiratory Viruses: A Systematic Review The Journal of Infectious Diseases 2021: volume 223, issue 4, pages 550-561
6. SAGE. Evidence of Wider Environmental Transmission of SARS-CoV-2 June 2020 (viewed on 25 April 2021)
7. Noorimotlagh Z and others. A systematic review of possible airborne transmission of the COVID-19 virus (SARS-CoV-2) in the indoor air environment Environmental Research 2021: volume 193, page 110612
8. Centers for Disease Control and Prevention (CDC). Science Brief: SARS-CoV-2 and Surface (Fomite) Transmission for Indoor Community Environments (updated 5 April 2021) 2021 (viewed on 10 May 2021)
9. Centers for Disease Control and Prevention (CDC). Science Brief: Community Use of Cloth Masks to Control the Spread of SARS-CoV-2 (updated 7 May 2021) 2020 (viewed on 10 May 2021)
10. Medicines and Healthcare products Regulatory Agency (MHRA). Regulating medical devices in the UK 2020 (viewed on 20 May 2021)
11. WHO. Mask use in the context of COVID-19 December 2020 (viewed on 10 May 2021)
12. Department of Health and Social Care. Guidance – Face coverings: when to wear one, exemptions, and how to make your own (updated 22 April 2021) 2021 (viewed on 10 May 2021)
13. Jefferson T and others. Physical interventions to interrupt or reduce the spread of respiratory viruses. Part 1 – Face masks, eye protection and person distancing: systematic review and meta-analysis medRxiv 2020: DOI 2020.03.30.20047217 (viewed on 10 May 2021)

14. Xiao J and others. Nonpharmaceutical measures for pandemic influenza in non-healthcare settings – personal protective and environmental measures Emerging Infectious Diseases 2020: volume 26, issue 5, pages 967-975
15. Brainard J and others. Facemasks and similar barriers to prevent respiratory illness such as COVID-19: A rapid systematic review medRxiv 2020: DOI 2020.04.01.20049528 (viewed on 10 May 2021)
16. Chu DK and others. 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 Lancet 2020: volume 395, issue 10242, pages 1973-1987
17. Gupta M and others. The use of facemasks by the general population to prevent transmission of COVID-19 infection: A systematic review medRxiv 2020: DOI 2020.05.01.20087064 (viewed on 10 May 2021)
18. Shea BJ and others. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both British Medical Journal 2017: volume 358, page 4008
19. Heneghan C and others. SARS-CoV-2 and the role of airborne transmission: a systematic review [version 1; peer review: awaiting peer review] F1000Research 2021: volume 10, issue 232 (viewed on 21 May 2021)
20. Public Health Agency of Canada (PHAC) Evidence Brief on SARS-CoV-2 Aerosol Transmission November 2020 (viewed on 21 May 2021)
21. Public Health Agency of Canada (PHAC). Rapid review on SARS-CoV-2 aerosol transmission, update 2 April 2021 (viewed on 21 May 2021)
22. Bak A and others. SARS-CoV-2 routes of transmission and recommendations for preventing acquisition: joint British Infection Association (BIA), Healthcare Infection Society (HIS), Infection Prevention Society (IPS) and Royal College of Pathologists (RCPath) guidance Journal of Hospital Infection 2021: volume 114, pages 79-103
23. Curran J and others. Transmission characteristics of SARS-CoV-2 variants of concern – a rapid scoping review March 2021 (viewed on 20 May 2021)
24. Ontario Agency for Health Protection and Promotion (Public Health Ontario). COVID-19 B.1.1.7 (501Y.V1) variant of concern – what we know so far February 2021 (viewed on 20 May 2021)
25. Ontario Agency for Health Protection and Promotion (Public Health Ontario). COVID-19 B.1.351 (501Y.V2) variant of concern – what we know so far February 2021 (viewed on 20 May 2021)
26. Ontario Agency for Health Protection and Promotion (Public Health Ontario). COVID-19 P.1 variant of concern– what we know so far February 2021 (viewed on 20 May 2021)
27. NERVTAG. Note on growth rate of SARS-CoV-2 B.1.1.7, 22 April 2021 2021 (viewed on 20 May 2021)

28. Chou R and others. Masks for Prevention of Respiratory Virus Infections, Including SARS-CoV-2, in Health Care and Community Settings: A Living Rapid Review Annals of Internal Medicine 2020: volume 173 issue 7, pages 542-555
29. Chou R and others. Update Alert: Masks for Prevention of Respiratory Virus Infections, Including SARS-CoV-2, in Health Care and Community Settings Annals of Internal Medicine 2020: volume 173, issue 5, page W86
30. Chou R and others. Update Alert 2: Masks for Prevention of Respiratory Virus Infections, Including SARS-CoV-2, in Health Care and Community Settings Annals of Internal Medicine 2020: volume 173, issue 7, page 132
31. Chou R and others. Update Alert 3: Masks for Prevention of Respiratory Virus Infections, Including SARS-CoV-2, in Health Care and Community Settings Annals of Internal Medicine 2020: volume 173, issue 12, page 169
32. Chou R and others. Update Alert 4: Masks for Prevention of Respiratory Virus Infections, Including SARS-CoV-2, in Health Care and Community Settings Annals of Internal Medicine 2021: volume 174, issue 2, page W24
33. Chou R and others. Update Alert 5: Masks for Prevention of Respiratory Virus Infections, Including SARS-CoV-2, in Health Care and Community Settings Annals of Internal Medicine 2021: volume 174, issue 4, page W47
34. Kim MS and others. Comparative Efficacy of N95, Surgical, Medical, and Non-Medical Facemasks in Protection of Respiratory Virus Infection: A Living Systematic Review and Network Meta-Analysis SSRN 2021 (viewed on 20 May 2021)
35. Tian C and others. Risk factors and protective measures for healthcare worker infection during highly infectious viral respiratory epidemics: a systematic review and meta-analysis Infection Control and Hospital Epidemiology 2021: pages 1-102
36. PHE COVID-19 Rapid Evidence Service. Face coverings in the community and COVID-19 – a rapid review (update 1) January 2021 (viewed on 20 May 2021)
37. ECRI. Cloth Face Coverings Worn by the Public to Reduce SARS-CoV-2 Transmission March 2021 (viewed on 20 May 2021)
38. Alberta Health Service. Double Masking and Improved Mask Fit COVID-19 Scientific Advisory Group Rapid Evidence Report March 2021 (viewed on 20 May 2021)
39. Bakhit M and others. Downsides of face masks and possible mitigation strategies: a systematic review and meta-analysis British Medical Journal open 2021: volume 11, issue 2, page 044364
40. SAGE. Masks for healthcare workers to mitigate airborne transmission of SARS-CoV-2, 25 March 2021 2021 (viewed on 21 May 2021)
41. Rothe M and others. A systematic review of mask disinfection and reuse for SARS-CoV-2 medRxiv 2020: DOI 2020.11.11.20229880 (viewed on 21 May 2021)

42. Verbeek JH and others. Personal protective equipment for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare staff Cochrane Database of Systematic Reviews 2020: issue 4

43. Hegde S. Which type of personal protective equipment (PPE) and which method of donning or doffing PPE carries the least risk of infection for healthcare workers? Evidence-Based Dentistry 2020: volume 21, issue 2, pages 74-76

Annex 1. Glossary

Aerosols are respiratory particles that can be any size between 0 and 100 microns (1, 2):

- **nasopharyngeal aerosols** are between 15 and 100 microns in size and usually only remain airborne for 1 to 2 metres (unless air velocity is high); they can penetrate to the deep lung on inhalation
- **thoracic aerosols** are between 5 and 15 microns and often remain airborne for over more than 2 metres; they can penetrate the thorax on inhalation
- **respirable aerosols** are <5 microns and remain airborne for long periods and can penetrate to the deep lungs on inhalation

Airborne transmission is the spread of infection from one person to another by airborne particles (aerosols) containing infectious agents

Basic reproduction number (R0) is the expected number of cases generated by one case in a population when everyone is susceptible to infection.

Droplets are respiratory particles >100 microns in size which have a ballistic trajectory and normally deposit within 2 metres of the index case.

Effective reproduction number (Rt) is the expected number of new cases generated in a population at a certain time period while factoring in immunity.

Face coverings are broadly defined as any type of face covering that covers the mouth and the nose (including medical masks and other types of masks).

FFP3 respirators have a 99%+ filtration efficiency (European classification). They are the equivalent to N99 USA classified respirators.

N95 respirator have a 95% filtration efficiency. They are equivalent to **FFP2 respirators**. FFP2 is the European classification and N95 is the USA classification.

Non-medical masks (also sometimes called 'cloth masks') are all masks other than N95 respirators and surgical masks.

Respiratory particles is used to refer to all particles produced by exhalation and carry infectious virus from infected sources. They are split into two categories based on size and behaviour in air (droplets and aerosols).

Source control designed to capture particles that are exhaled by the wearer and acts to reduce the amount of virus that is released into a space.

Surgical masks (also called 'medical masks') are flat or pleated masks that are fixed to the head with straps that go around the ears or head or both.

Universal masking is when everyone, with some exceptions, is required to wear a mask.

Variants of concerns refers to variants of a virus that show evidence of increased transmissibility, more severe disease, reduced effectiveness of treatments or vaccines, reduction in neutralisation by antibodies from previous infection or vaccination or diagnostic detection failures.

Wearer protection refers to protection conferred to an unaffected person (the wearer) through reducing their exposure to the virus-containing respiratory particles.

Annex 2. Searching methods

Searches were completed to identify any existing reviews (systematic or rapid) on SARS-CoV-2 from August 2020 onwards, related to each of the 3 topics.

An Information Scientist searched (using terms specific to each topic) and browsed a number of COVID-19 review repositories and prospective review registers (see list below).

COVID-19 review repositories and prospective review registers:

- Agency for Clinical Innovation, COVID-19 Critical Intelligence Unit
- Cochrane question bank and Cochrane reviews
- COVID-19 Best Evidence Front Door, University of Michigan
- COVID-19 Quick Response Reports for the NL Health System
- ECDC
- ECRI
- Epistemonikos, COVID-19 L.ove
- HIQA, Ireland
- Lenus, The Irish Health Repository
- McMaster forum
- National Collaborating Centre for Methods and Tools, McMaster University
- NIHR Applied Research Collaboration (ARC) West, COVID-19 rapid reports
- Norwegian Institute of Public Health
- Oxford COVID-19 Evidence Service
- Prospero
- Public Health Wales Observatory, rapid evidence summaries
- SAHMRI-based Health Policy Centre
- COVID-19 Evidence Synthesis
- UNCOVER (Usher Network for COVID-19 Evidence Reviews)
- VA Evidence Synthesis Program
- WHO COVID-19 database

Additionally, we searched for any relevant reviews available in:

- COVID-19 portfolio (which includes preprints)
- LitCovid
- PHE COVID-19 Evidence Systematic review updates (a spreadsheet and Endnote library of reviews, compiled from searches of Medline, Embase, medRxiv, SSRN and WHO COVID-19 database, started on 19 Oct 2020 and updated every 2 weeks)
- SAGE scientific evidence
- TRIP database

About the UK Health Security Agency

The UK Health Security Agency is an executive agency, sponsored by the Department of Health and Social Care.

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