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Face masks and coverings for the general public: Behavioural knowledge, effectiveness of cloth coverings and public messaging

This rapid review of the science of the effectiveness of different face mask types and coverings and behavioural adherence is from the Royal Society and the British Academy to assist in the understanding of COVID-19.

This paper is a pre-print and has not been subject to formal peer-review.

SUMMARY KEY POINTS

- Cloth face coverings are effective in reducing source virus transmission, i.e., outward protection of others, when they are of optimal material and construction (high grade cotton, hybrid and multilayer) and fitted correctly and for source protection of the wearer.
- Socio-behavioural factors are vital to understanding public adherence to wearing face masks and coverings, including public understanding of virus transmission, risk perception, trust, altruism, individual traits, perceived barriers.
- Face masks and coverings cannot be seen in isolation but are part of 'policy packages' and it is imperative to review interrelated non-pharmaceutical interventions in tandem including hand hygiene, sanitizers and social distancing when maintaining the 2 metre or 1 metre+ distancing rule is not possible.
- Consistent and effective public messaging is vital to public adherence of wearing face masks and coverings. Conflicting policy advice generates confusion and lack of compliance. Populations without a previous history of mask wearing have rapidly adopted face coverings during the COVID-19 period.

Executive summary

- Cloth face masks and coverings for the general public are effective in improving: i) source protection, i.e., reduced virus transmission from the wearer when they are of optimal material and construction and fitted correctly; and ii) wearer protection, i.e., reduced rate of infection of those who wear them.
- Optimal cloth face coverings are made from specific material (e.g., high grade cotton), hybrid and multilayer constructions (e.g., silk-cotton) and need to be fitted correctly.
- Many countries implemented a policy requiring the general public to wear face masks and coverings in all public places by mid-March 2020.
- Countries with no previous history of wearing face masks and coverings amongst the general public rapidly adopted usage such as in Italy (83.4%), the United States (65.8%) and Spain (63.8%) by the end of April 2020.
- A systematic review isolated key socio-behavioural factors to understanding public adherence to wearing face masks and coverings, namely:
    - public understanding of virus transmission, including efficacy of source versus wearer protection, diagnostic uncertainty and inability to self-diagnose.
    - risk perception, individuals' underestimation of health risks and perception that protection is only relevant for vulnerable groups, or outside of their proximity.
    - previous national pandemic experience resulting in rapid response and socio-political systems, allowing for more or less coordinated action and public trust.
    - individual characteristics, such as younger people and men having a lower threat perception and compliance with interventions.
    - perceived barriers, lack of supply of surgical masks and perceived competition with medical resources, resource constraints to obtain coverings, comfort and fit.
- Consistent and effective public messaging is vital with non-pharmaceutical interventions more effectively seen as part of 'policy packages' to acknowledge:
    - interventions as interrelated, to be reviewed in tandem with face masks and coverings related to hand hygiene, sanitizers and social distancing when maintaining the 2 metre or 1 metre+ distancing rule is not possible.
    - public communications must be clear, consistent and transparent with inconsistent, premature, alarmist information or that without a clear source raising scepticism and lowering compliance.

Conclusion

In England face masks and coverings for the general public in public places have not been mandated beyond public transport and hospitals. Wearing a face mask or covering in the UK has had very low uptake (~25%, late April 2020). The lack of clear recommendations for the general public and low uptake of wearing face masks and coverings may be attributed to: (i) over-reliance on an evidence-based medicine approach and assertion that evidence was weak due to few conclusive RCT (randomised controlled trial) results in community settings, discounting high quality non-RCT evidence. There have been no clinical trials of coughing into your elbow, social distancing and quarantine, yet these measures are seen as effective and have been widely adopted; (ii) inconsistent and changing advice from supranational organisations (WHO, ECDC) and other nations with variation in policy even within the UK; (iii) concern over the applicability of findings across multiple settings (health care versus general public, other pandemics and countries), yet many 'lessons learned' from previous pandemics, including public wearing of face masks and coverings, repeat themselves during COVID-19; and, (iv) mix of supply concerns of PPE shortages of surgical face masks with recommendations for face mask and covering wearing for general public.

Contents

1. Introduction and motivation

As many countries evaluate changes in non-pharmaceutical interventions to counter the spread of COVID-19, considerable focus has been given to the use of face masks and coverings (see Box 1) and related interventions. Next to hand washing and social distancing, face masks and coverings are one of the most of widely adopted non-pharmaceutical interventions for reducing the transmission of respiratory infections. As outlined in the Royal Society's DELVE report on face masks for the general public, their review concluded that asymptomatic and presymptomatic individuals are infectious, respiratory droplets are a major mode of transmission and face masks reduce droplet dispersal[1]. Face masks and coverings that are made of optimal material and have a good fit can provide protection for both the wearer, but also those around them. For this reason, many nations have already introduced them, such as the United States in early April 2020[2], with the WHO recommending their use by the general public in early June[3] along with international experts urgently calling for their introduction for the public during the COVID-19 crisis[4].

At the time of writing, they have not been adopted for the general public in England and various other countries and there appears to be several gaps in our existing knowledge on the subject of face masks and coverings. This report contributes the following to inform current knowledge and policy-making on face masks and coverings. First, we present existing knowledge about the effectiveness of cloth masks and face coverings, a meta-analysis of existing studies to demonstrate their protective ability in a health care setting and the effectiveness of cloth masks in effective filtering of the transmission of the virus (i.e., protecting others). Second, we present an international comparison of the timing and introduction of face mask policies in relation to COVID-19. Third, existing reviews on this topic have largely focussed on medical or transmission aspects related to face masks, with a lack of attention to the behavioural factors underlying perception and adherence to usage. This relates to the fourth contribution, which is providing a more systematic literature review, also beyond medical and clinical literature[5] to broader sources and databases. This allows us to evaluate comprehensive themes about face mask and covering behaviour with interrelated non-pharmaceutical interventions such as social distancing and hygiene measures and embeds the face mask literature across a wider range of topics and more extensive period of time. In turn, it likewise allows us to learn from behavioural knowledge reaped from previous respiratory infections and pandemics.

2. Effectiveness of cloth face coverings

2.1 Background and existing knowledge: health care settings of surgical masks and respirators

Current knowledge on the effectiveness of face masks to prevent virus transmission from COVID-19, SARS, MERS and H1N1 is mostly limited to studies of surgical masks and N95 respirators. The majority of existing studies are conducted in health care settings and focus on protection of the mask wearer as opposed to wearing a mask for the protection of others. This distinction is vital since mask wearing for the general public occurs in non-clinical situations (home, public transport, shops, restaurants) and involves both protection of oneself but also others. Surgical masks and N95 respirators were included in the most recent systematic review and meta-analysis published in the Lancet[6]. Based on 29 studies, the authors concluded that the use of both N95 respirators and surgical masks (including similar re-usable masks) were associated with large reductions in virus transmission. In this meta-analysis, they also found that mask wearing in non-health care settings is protective and statistically significant (RR=0.56, CI 0.40-0.79). There were, however, some concerns about this study including difficulty in separating effects of different types of PPE (masks, eye protection), potential confounders and the transferability of results to community settings.Another meta-analysis found that medical masks provided similar protection to N95 respirators in protecting against viral respiratory infections in healthcare settings[7]. We emphasise that the majority of studies have been conducted in health care settings and there are therefore caveats in the ability to transfer results directly to community settings (see Appendix 5, GRADE recommendations). Protective equipment in health care settings may be more effective because of training, knowledge and the environment. As we note in relation to 'package policies' (Section 5.3), masks are generally introduced as one of many policies such as hand hygiene and distancing and thus difficult to examine in exclusion. Both distance but also duration of contact are likewise vital (but rarely examined), which may differ across settings.

BOX 1

Face mask versus face coverings

Masks often refer to surgical or respiratory masks that medical staff use whereas coverings encompass broader types and materials such as homemade cloth masks. Not all masks and coverings are equal, with filtration comparisons discussed later in this report.

Respirators
N95, FFP1/2/3 and other forms are seal-tested respirator masks that protect health care workers. These masks seal around the nose and mouth, have tangled fibres that contain filters. We note that there are also differences amongst these such as those with and without valve protection, which we do not discuss here.

Surgical masks
This is a form of personal protective equipment (PPE) worn by health workers that fits loosely over the nose and mouth, often blue squares that hook over the ears.

Cloth face coverings
These are face masks that can be purchased or made in the home using a variety of fabrics. Research on a variety of fabrics and patterns of face coverings has shown that tightly woven fabrics such as cotton, denim or tea cloths filter the best and that a combination of multiple layers is the most effective. Loosely woven fabrics like a scarf have been shown to be the least effective. Attention must also be placed on how well it fits on the face; it should loop around the ears or around the back of the neck for better coverage.

2.2 Evidence of effectiveness of public wearing of masks and coverings in community-based studies

A repeated concern raised by some is that there are few randomised control trials (RCTs) with conclusive results examining the effectiveness of face masksconducted in community settings. As we discuss in relation to our GRADE recommendations in Appendix 5, and as others have noted, RCTs are challenging for evaluating face masks in a public setting given both the ethical and practical considerations[8, 9]. This echoes experts in the field who have urgently called for the implementation of face masks and coverings for the general public[10]. We note that there have also been no clinical trials of coughing into your elbow, social distancing and quarantine, yet these measures have been widely adopted and are considered as effective.

A recent study identified 10 RCTs that examined the effectiveness of facemasks on reducing influenza virus infection in the community from 1946-2018[11]. The study did not distinguish estimates by the type of mask but did examine masks in combination with hand hygiene. The RCTs were heterogeneous across community settings ranging from Hajj pilgrims, university and households settings. In a pooled meta-analysis, the authors conclude that there was no significant reduction in influenza transmission with the use of face masks (RR 0.78, 95% CI 0.51-1.20, p=0.25). But notably, the authors state that: “most studies were underpowered because of limited sample size, and some studies also reported suboptimal adherence in the face mask group.”

They concluded that "In theory, transmission should be reduced the most if both infected members and other contacts wear masks, but compliance in uninfected close contacts could be a problem."

A non-peer reviewed medRxiv pre-print meta-analysis of around 20 studies* (cluster-RCTs, cohort studies, case-control, cross-sectional) conducted in community settings concluded that wearing a face mask slightly reduces the odds of infection by the wearer by around 6%[12]. Observational studies found greater effectiveness. They concluded that RCTs likely underestimated efficacy due to poor compliance and that observational studies likely over-estimated efficacy because of self-reported symptoms and confounding. They also found that face mask wearing was consistently protective across settings including the general community, schools and universities, and visits to health care clinics. They concluded that face mask wearing was probably not protective during mass gatherings, but they note this should be judged with caution since they are drawn only from Hajj pilgrimage studies. Pilgrimages would have different multiple transmission pathways and a longer duration of recurrent contact. A major limitation noted by the authors was that the type of face mask was rarely explicitly stated in the studies and they had to infer masks were of surgical grade, leaving no indication of the effectiveness of cloth or non-surgical masks or coverings for the general public.

Although there are few community-based RCTs, there is evidence from mask wearing that occurred within the public in Beijing[13], which examined the transmission of COVID-19 within families and close contacts of 335 people in 124 families from 28 February to 27 March 2020. They found that face mask use before the family member developed symptoms was 79% effective but that wearing a mask after the onset of illness was not significantly protective. The risk of transmission in the household was 18 times higher with those who had frequent daily close contact with the infected family member, compared to those who did not. A combined study in Hong Kong examining hospital workers and household members of SARS patients (N=1,192) found that frequent mask use in public venues, frequent hand washing and disinfecting living quarters were significantly protective factors[14]. A case-control study in Beijing of 94 unlinked and 281 community-based controls found that case patients (i.e., became infected) were more likely to have chronic medical conditions, eaten outside the home or taken taxis frequently and that the use of masks was strongly protective[15]. Another study was conducted in a community setting in Vietnam of nine persons with serological evidence of SARS from a sample of 212 close contacts but does not have a specific focus on face masks, but does confirm a higher risk for direct carers of those who are infected[16]. As noted previously largely due to the experience of previous respiratory infections, the wearing of masks in the community is strongly recommended in many Asian countries, with high to almost universal uptake.

Our literature review revealed that no systematic review and meta-analysis had yet been conducted on the effectiveness of other types of cloth masks beyond surgical masks and N95 respirators. As noted above, reviews that did exist focussed on surgical and R95 respirators in health care settings[17] or did not distinguish between the type of mask[18]. A meta-analysis scrutinizing the effectiveness of these alternative mask types is therefore a contribution, given that cotton and paper masks are being recommended by some governments[19] and that there is difficulty in sourcing surgical masks for the general public. As noted in the GRADE evaluation of our work in Appendix 5, and above, there are two strong caveats to our meta-analysis. First, it has been conducted in a health care setting and second, that all studies focus on source protection (i.e., protecting the wearer). In a community setting different circumstances would be at play and protection would be both of oneself but also in blocking transmission to protect others. A strength of this analysis is that the studies are in a relatively homogenous setting.

* We note 'around 20' since different numbers are reported in the text and figures. In the results section, 31 studies are listed of which 28 were reported as suitable for meta-analysis yet 21 studies are listed in the meta-analysis results (Figure 2).

2.3 Meta-analysis of cloth and paper masks of protection of wearers in health care settings

We identified four potential studies and further cross-reference checks and analysis of existing systematic reviews on face masks revealed one additional non-English language study (see Table 1, Yin *et al.* 2004). One of the studies did not pass our eligibility criteria due to the absence of a clear control group (i.e., they lacked a 'no mask' control group and compared only medical versus cloth masks)[20]. The excluded study was conducted in a healthcare setting in Vietnam and is notably the only RCT study on cloth masks. Another important eligibility criterion was the presence of separate estimates on cotton and paper masks. Our meta-analysis is thus based on four quantitatively comparable studies which provide five estimates from healthcare settings in China (Table 1). One article[21] was in Chinese, which we able to have translated and obtain the necessary information.

2.4 Mask types and outcome as risk of infection

The primary outcome of interest was risk of infection, with three studies providing statistics for SARS cases and one for influenza A H1N1. Cotton masks include cloth masks and ≥12-layer gauze masks, following specifications provided in the studies. Estimates of gauze masks are included due to the fact that some Chinese healthcare workers made their own masks from layers of gauze during the SARS outbreak[22]. The second mask type of interest are alternative masks made from paper, also used during the SARS epidemic.

TABLE 1

Characteristics of comparative studies included in mask type meta-analysis.

Study	Country	Setting	Virus	Type of study	Comparison groups		Sample size	Main findings
					Control group	Intervention group		
Zhang *et al.* 2012[150]	Beijing, China	Health care	H1N1	Case-control	No face mask; 16.6% infected	Cloth face mask; 20.5% infected	56	Cloth mask use did not significantly decrease the risk of infection in health care setting
Liu *et al.* 2009[151]	Beijing, China	Health care	SARS	Case-control	No face mask; 12.1% infected	≥12-layer gauze; 6.5% infected	477	Healthcare workers who wore cotton masks had significantly lower risks of infection
Seto *et al.* 2003[152]	Hong Kong, China	Health care	SARS	Case-control	No face mask; 13.3% infected	Paper mask; 7.1% infected	111	Healthcare workers who wore paper masks had lower risk of infection
Yin *et al.* 2004[153]	Guangdong Province, China	Health care	SARS	Case-control	No face mask; 81.8% infected	a. ≥12-layer gauze; 22.8% infected b. Paper mask; 50% infected	a. 213 b. 55	Healthcare workers who wore both types of masks had lower risk of infection

2.5 Data analysis

We quantify associations of mask use with incidence of infection by employing standard random effects meta-analysis. We assess risk ratios (RRs) with 95% confidence intervals (CIs) and performed subgroup analysis by face mask type. Due to the small number of studies, we were unable to perform additional sensitivity analyses (e.g., differences by country or different settings). Since our sample is relatively homogenous with respect to research design, country, and health care setting, we do not expect inter-study heterogeneity to seriously bias our results. As noted in the limitations, the low number of studies is, however, one concern. We also performed Begg's and Egger's tests which did not reveal presence of significant publication bias (P>0.05).

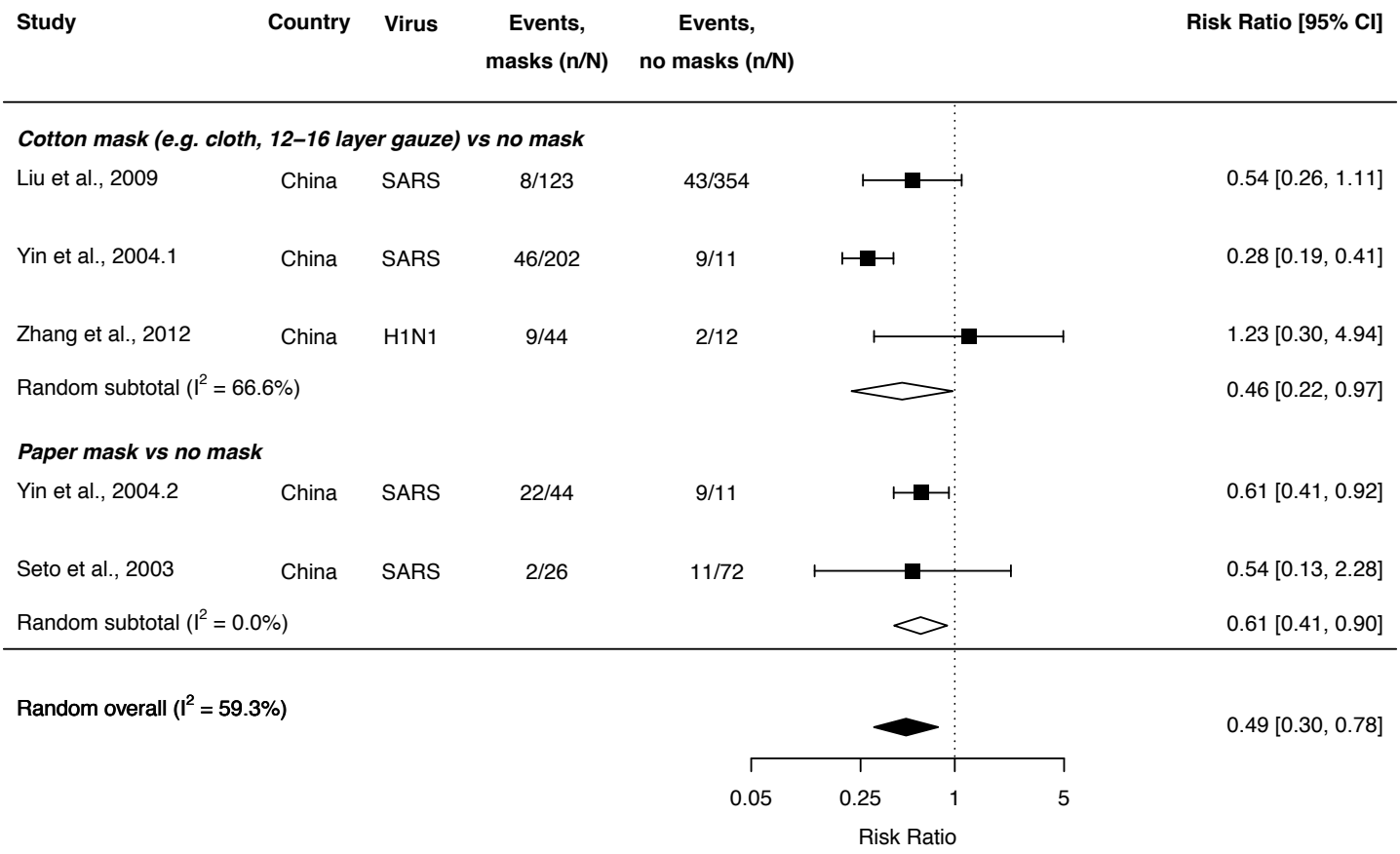
2.6 Meta-analysis results: Cotton masks associated with infection reduction

The results of meta-analysis are shown in Figure 1 with pseudo 95% CIs (see also Appendix 3, Fig A3.2). For SARS and H1N1 infections, the use of both cloth/≥12-layer gauze and paper masks is associated with a statistically significant reduction of the infection risk (pooled RR=0.49 with 95% CI: 0.30 to 0.78, N=888). However, there is considerable heterogeneity in the findings (I^2=59.3%* and significant Q-test with P=0.03). The use of cotton masks is associated with a 54% lower relative odds of infection in comparison to the no mask groups (RR=0.46; 95% CI: 0.22-0.97; N=746) with a coefficient heterogeneity I^2 of 66.6% (Q-test P=0.05). For paper masks, the relative odds of infection were 39% lower than in the no mask group (RR=0.61; 95% CI: 0.41-0.90; N=166; I^2=0.0%). On average, we can conclude that cotton masks exhibit a greater protective potential than paper masks. The results on paper masks should be interpreted with caution since there are only two estimates that emanate from small samples in comparison to the cotton masks studies and particularly the comparatively larger sample sizes in previous meta-analyses on surgical and N95 respirators[23]. Once again, we note that this is about the protection of the wearer and not about reducing spread, which we cover in the next section. We also note that these are case-control studies and do not show causal relationships.

* We use I^2 statistics to quantify between-study heterogeneity, where I^2>50% representing a potential for substantial heterogeneity. Notably, it is not uncommon in medical meta-analyses to have a I^2 of 80%.

FIGURE 1

Forest plot of risk ratios of the association of cotton and paper mask use with viral infection causing SARS and influenza A H1N1.



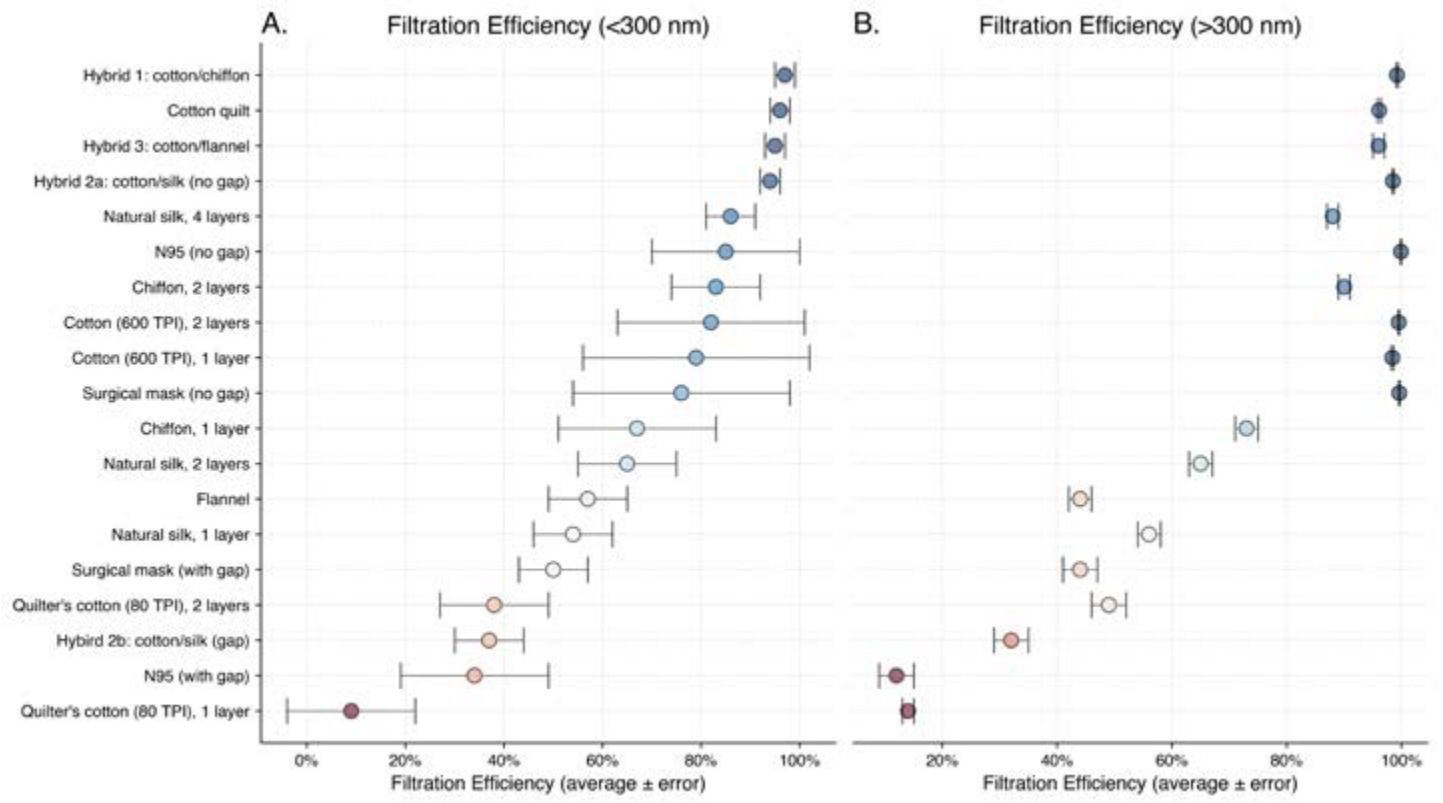
2.7 Face masks for protection of others: Effectiveness of cloth face masks varies by fabric type, mask construction and gaps

As the previous meta-analysis demonstrates, the type of face covering is essential, but it focussed on the protection of the wearer. Another persistent question is: Are certain types of cloth face coverings that can be easily made in the home or purchased more protective to shield transmission of infection to others? Although there is currently limited evidence on this in relation to COVID-19, a recent study published April 24 2020 examined the performance of various commonly available fabrics used in cloth masks and coverings. Note that the COVID-19 virus produced by an infected person is in the respiratory mucus and distributed out in larger particles, making the type of fabric and ability to penetrate this fabric important. A variety of common fabrics and their combinations were used including cotton, silk, chiffon, flannel and various synthetics.

Figure 2 takes their original results and plots them on a graph to visually demonstrate the differences in mask filtration ability by several types of masks. The central conclusions are that: (i) filtration for various fabrics when a single layer is used performs relatively worse, ranging from 5-80% and 5-95% for particle sizes of <300 nm and >300 nm respectively. (ii) cotton (particularly high grade thread counts) is particularly good at filtration, and this was (iii) particularly with more layers cotton (600 TPI, 2 layers) (99.5 ±0.1 error) whereas (iv) a hybrid material of (cotton-chiffon, cotton-silk, cotton-flannel) performed the best at >80% (particles <300 nm) and >90% (for particles >300 nm). They concluded that this enhanced performance of hybrids was likely related to the combination of mechanical and electrostatic-based filtration. Finally (v), the effectiveness of all masks, including N95, surgical and cloth masks were seriously reduced when a gap was introduced, suggesting the importance of proper fit and usage.

FIGURE 2

Filtration efficiencies of various fabric type test specimens (error).



Source: Adapted from Table 1[154]. Note: The figure shows filtration efficiencies at a flow rate of 1.2 CFM.

The authors therefore conclude from this study that combinations of various commonly available fabrics used in cloth masks and face coverings can provide significant protection against the transmission of aerosol particles.

3. International face mask and covering policies

3.1 Varied and changing nature of policy information

International face mask policies, often in the form of recommendations, have been introduced across many countries in relation to COVID-19. Within these policies there has been a distinction between recommendations for respiratory (e.g., N95) and surgical masks for medical and health care workers, versus face coverings (e.g., homemade of fabric) for the general community. A definition of different types of masks and coverings and terminology can be found in Box 1, with a more detailed explanation on the effectiveness of fabric and material differences between cloth masks described later in this report.

Notably, policies on face masks and coverings in relation to COVID-19 have changed over time and been varied and inconsistent between large supranational organisations such as the World Health Organization (WHO) and advice provided by various countries and regions (e.g., states, provinces) within them. As of March 14 2020, 67 countries had introduced policies, with many more implementing policies between April and May 2020 (Figure 3A)[24]. The majority of the facemask policies were inaugurated on March 14, three days after the WHO declaration of the coronavirus outbreak as a pandemic. On April 6 2020, the World Health Organization (WHO) recommended that healthy people in the community did not need to wear a mask, and that they should be worn only by those who are feeling unwell and are coughing and sneezing, as well as caring for someone who is infected[25]. Advice from the European Centre for Disease Prevention and Control (ECDC) issued a similar statement on April 8 2020. Here they stated that there was “no evidence that non-medical face masks or other face covers are an effective means of respiratory protection” and that there is “limited indirect evidence showing that non-medical face masks made from various materials may decrease the release to the environment of respiratory droplet produced by coughing.”[26]

Conversely, there was almost universal mask wearing without any policy in certain Asian countries that had previous experience with SARS, which we explore in the next section.

Large countries that had no previous history of face coverings also adopted new measures. On April 3 2020, in light of knowledge that a significant portion of individuals with COVID-19 are asymptomatic and can still transmit the virus[27], the United States Centre for Disease Control and Prevention (CDC) recommended wearing non-surgical cloth face coverings in public settings where social distancing is hard to maintain (e.g., grocery stores). They also specifically noted that they did not advocate the use of surgical masks for the general public[28]. We note that in the same week, the CDC recommended the use of non-medical face masks while the ECDC stated that non-medical face masks are not effective.

Then on June 5 2020, WHO published a correction of their statement in early April with updated guidance recommending that governments across the world should recommend that the public should wear face masks in public areas to help reduce the spread of COVID-19[29]. This included encouraging mask wearing where there is widespread transmission and physical distancing is difficult, such as on public transport, in shops or in other confined or crowded environments. The WHO stressed that face masks were one of a range of tools to reduce the risk of viral transmission and that face masks should not give a false sense of protection.

Across the United Kingdom recommendations and mandates have varied considerably. On April 28 2020, Scotland provided recommendations (not mandatory) that the public should wear face masks in enclosed spaces where social distancing is difficult to achieve. This was followed by mandatory wearing on public transport as of June 22 2020[30]. On June 9 2020, Wales recommended that face coverings could be used where it might be difficult to stay 2 meters away from others and advised using three-layer non-medical face coverings[31]. England formally introduced its first face mask policy in early June, mandating that as of June 15 2020, face coverings were mandatory on public transport[32]. Although there has been some public messaging about wearing face coverings in England, which we explore in a later section, this has not been in the form of clear and consistent formal advice.

3.2 Face mask requirements and recommendations: An international comparison

As shown in Figure 3 (panel A), as of June 15 2020, most countries (121 of 188 where data is available) required face masks to be worn in the entire country, 19 in parts of the country only, 28 did not require mask wearing, 14 recommended masks or covering, but did not require mask-wearing and 6 Asian countries had no requirements, but experienced virtually universal usage**. In Asian nations such as China, Taiwan or Hong Kong, masks were already common even before the coronavirus pandemic, credited to populations accustomed to wearing coverings due previous experience with the SARS and H1N1 outbreaks, or pollution[33]. The use of face masks is also not new in Latin America and were mandatory during H1N1 for instance in Brazil[34] and Mexico[35].

3.3 Location of mask wearing policy

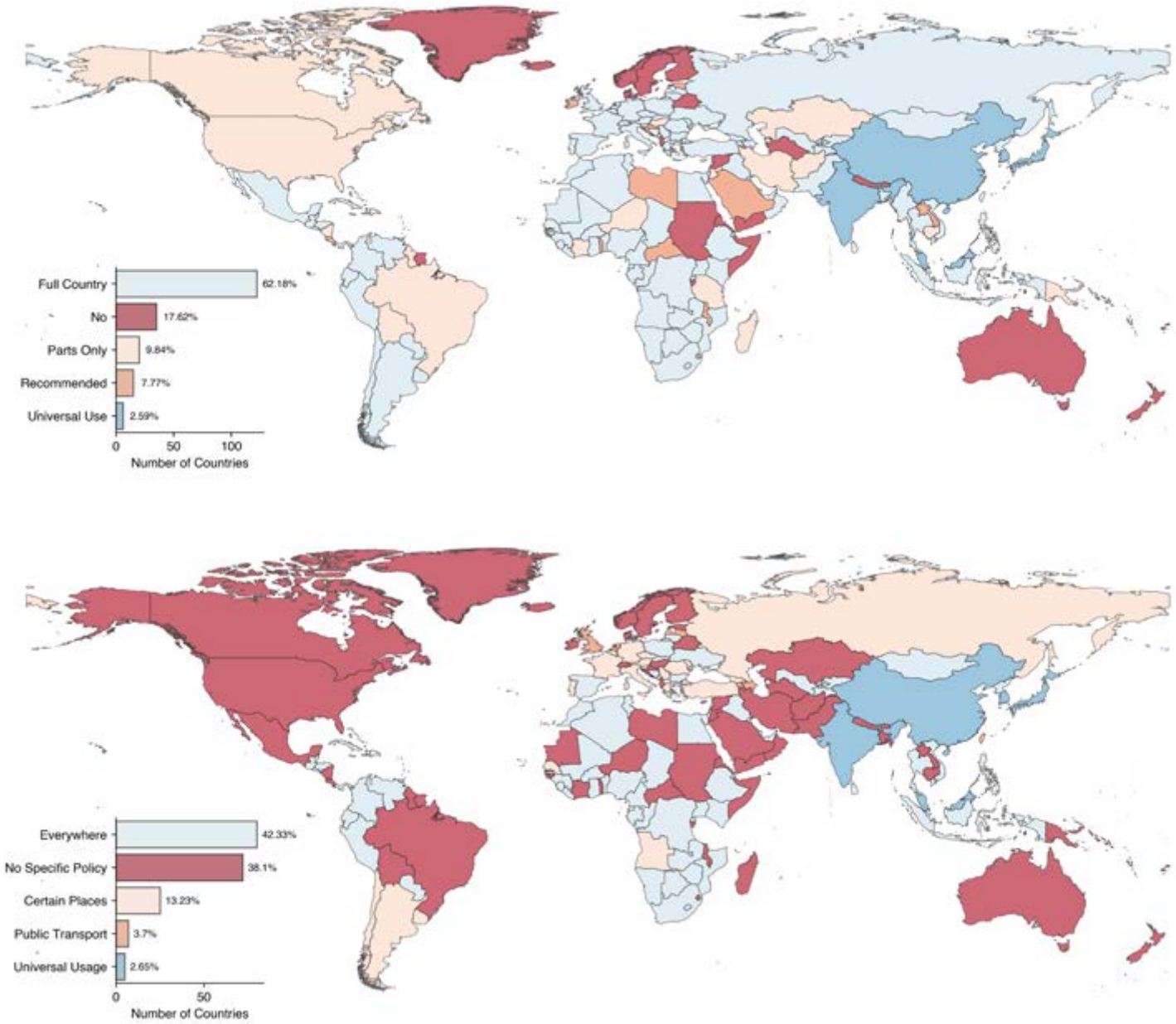
Policies also vary by the location of where facemasks are mandated. We illustrate measures of as of June 15 2020 in Figure 3B with detailed policy categories described in Table A1.1. Policies can be largely grouped into:

- mask wearing required for everyone in public places (71 countries).
- only indoor places (e.g., in relation to social distancing, type of indoor space (15 countries),
- public transport and crowded places (in relation to number of people, social distancing and venue) (12 countries),
- certain public places (major cities only, in relation to social distancing) (9 countries),
- public transport only (7 countries)
- universal mask usage but no formal policy (6 countries)

** China, Hong Kong, India, Japan, Malaysia, South Korea.

FIGURE 3

Face mask policies across the world.



Source: Masks4all data[155] data as of June 15 2020. This source is regularly updated and corrected but is not an official governmental or supranational source. The authors used the information as provided in good faith, and note that each source for national policy is linked to an external source. Notes: Panel A, data available for 188 countries. Panel A. Full country (121); Parts of country (19), No (28); No, but recommended (14); No, but universal usage (6). Panel B see Appendix 1, Table A.1. Panel B, data available for 120 countries.

4. Behavioural factors related to face mask adherence: Systematic literature review

4.1 Data collection systematic review

Following the PRISMA[36] and MOOSE[37] reporting guidelines (see Appendix 2 Methods), we developed several customized Python functions to undertake a systematic review across the three databases of PUBMED, Scopus and Web of Science (WoS), building on previous scientometric work in genetics[38, 39]. Given the comparatively slower publication pace of the social and behavioural sciences, also noted elsewhere[40], we also included some pre-print non-peer reviewed articles and note this fact where mentioned and in our GRADE recommendations[41] of the quality of evidence (see Appendix 5). This extended search allowed the inclusion of non-medical literature including materials (e.g., face mask materials) and socio-behavioural literature. We expanded the queries to include search terms related to multiple derivations of face masks and coverings (e.g., facemask, face mask, N95 respirator, surgical mask, FFP3, cloth mask, face covering, all search queries available upon request). Given the relatively recent nature of the COVID-19 pandemic and to obtain a richer body of literature and lessons learned, in addition to research on COVID-19 and coronavirus, we also included previous respiratory pandemics such as the 1918 Spanish flu, severe acute respiratory syndrome (SARS), H1N1 influenza, Middle East respiratory syndrome (MERS), H5N1 influenza and flags for additional policies on social distancing and isolation. More detailed information on study selection can be found in Methods (Appendix 2, Figure A2.1).

The aim of this rapid review was to focus on behavioural factors related to compliance, with five central themes that emerged: i) public understanding of the virus, ii) risk perception, iii) previous national experience with pandemics, socio-political systems, and trust in government and science, iv) individual characteristics; and, v) perceived barriers. Most of these themes have been previously identified such as for example, in a review of qualitative research of SARS and H1N1 in 17 studies[42] and a systematic review of 9 bioevent studies in the United States[43], but themes also differ due to the wider breadth of the literature reviewed here, additional focus on COVID-19 and international literature.

4.2 Public understanding of virus transmission

A central theme that emerged from the literature on public adherence to face mask and coverings is the importance of personal and cultural beliefs and understanding of how respiratory viruses are spread. Core factors are: (i) understanding how it is spread and, importantly, whether asymptomatic individuals can transmit the virus, (ii) whether mask wearing is for one's own individual protection or to protect others, (iii) clarity on diagnosis of COVID-19 and inability and reticence to self-diagnose; and, (iv) efficacy to adopt the required behaviour of face mask or covering usage to counter the threat.

A systematic literature review of previous respiratory pandemics (SARS, H1N1) found that the general perception of how respiratory viruses are transmitted is that it is by air, only within a particular proximity, by symptomatic others only and more likely in cold ambient and water temperatures[44]. For COVID-19 as with other respiratory viruses, droplets are produced when an individual coughs, sneezes, talks or breaths, which then convert to aerosols and become airborne. Droplets can land on surfaces and can remain viable. Aerosols are much smaller than droplets and thus can more easily penetrate different types of material. Knowledge rapidly changed about COVID-19 transmission, particularly in the early phases, with a growing number of studies demonstrating sizeable levels of asymptomatic transmission[45].

A related issue is the understanding of whether face masks are used for individual protection against contracting the virus versus wearing one to protect others. An international poll of face mask wearing during March 12 to April 12 across 15 countries examined this (N=29,000, ~2,000 per country)[46]. In the UK (41%), Australia (47%), Russia and Canada (35%) a sizeable proportion did not see the value in wearing a face mask if they were not sick, suggesting that they were not aware of asymptomatic transmission. This is not entirely surprising, also in light of WHO and other national advice that had initially focussed on individual mask wearing for only infected individuals to protect others in early April 2020.(19) This is compared to comparatively lower levels reporting the same in Vietnam (7%), China (9%), Japan (11%), but also Spain (8%) and Italy (9%), all nations that had adopted or continued to have high levels of face mask wearing by mid-April 2020. As noted previously, this could be related to the different phases of the outbreak. Respondents in the UK showed the lowest levels of understanding that face masks can be worn to protect others with 15% reporting 'I expect people around me to wear a face mask so I don't get sick' compared to for instance Japan (58%) or Vietnam (55%).

During both SARS, H1N1 and repeated again with COVID-19, there was also high diagnostic uncertainty particularly at the start of the pandemic, which challenges individuals' ability to self-diagnose. Particularly during H1N1, but also COVID-19, individuals expressed doubts about their ability to identify symptoms and whether and how they could distinguish between the pandemic and seasonal flu symptoms. Studies in the UK[47, 48] and New Zealand[49] of the H1N1 outbreak found that individuals had strong fears and concerns about their own judgement and ability to self-diagnose, which in turn influenced their behaviour in relation to self-isolation and use of remote healthcare. During H1N1, the 'vagueness' of the symptoms and differentiating them was listed as a central challenge for individuals. Indeed alternative data collection of 'real-time' tracking crowdsourced a wide variety of COVID-19 symptoms across a spectrum of mild to serious systems ranging from loss of smell and taste to breathing difficulties, which at that time had not been included as symptoms in many countries[50].

Finally, the manner in which individuals in the community respond to the threat of a respiratory infection is influenced by their beliefs about the efficacy of the intervention and perceived costs of protective behaviours[51]. Efficacy refers to the beliefs about an individuals' ability to successfully adopt behaviours and the effectiveness of adopting behaviours in eliminating the health threat. Literature from the SARS coronavirus outbreak and H1N1 2009 pandemic found that perceptions of risk, anxiety about the infection and the efficacy of the intervention are pivotal[52, 53, 54, 55, 56, 57, 58, 59, 60]. Behavioural change is highly contingent on the communication of risk, individual appraisal of risk and the perceived ability to make the change[61]. A literature review of over 65 studies examining over 20 public health issues for instance, concluded that the key factors driving behavioural change are increases in threat severity, threat vulnerability, response efficacy and self-efficacy facilitated adapted intentions or behaviours[62]. We return to this topic later in this section when we discuss barriers, conflicting policy advice and confusion about the effectiveness of face masks and coverings, which in turn impacts the efficacy individuals' would place on adopting face mask and covering interventions.

4.3 Risk perception: perceived likelihood of infection and perceived benefits

A clear theme that emerged in the literature was the importance of individual risk perceptions, the notion of 'othering' and belief that 'it won't happen to me'. Core factors related to this theme are an: (i) overly optimistic risk assessment of not contracting or transmitting the virus, (ii) incorrect judgements about the role of proximity; and, (iii) denying personal risk via 'othering' by blaming or differentiating oneself from vulnerable groups perceived to be at a higher risk.

A central challenge isolated in the literature is that many individuals view themselves as less vulnerable and more capable than others, generally underestimating health risks, finding it unnatural to respect strict isolation to protect others and have only a limited awareness of actions that pose a health risk[63]. A number of studies focus on individuals' incorrect assessment of risk and overly optimistic sense they will not contract the virus. A study of SARS in Canada, for instance, found that a common aspect of risk perception was the denial about their risk of contracting SARS because they did not feel sick[64]. Individuals' optimism can in turn lead to an underestimation of contracting COVID-19 and thus ignoring public health messages A study of 1,591 US-based individuals in the first week of the COVID-19 pandemic from March 11-16 2020 examined individual's perception of risk [65]. Within five days, as they gained awareness about the virus, perceptions of risk increased yet they still underestimated their personal risk of infection. This, however, substantially varied amongst individuals, isolating a subgroup of those who persistently remained disengaged, unaware and did not practice any protective behaviour. A pre-print non-peer reviewed study on medRxiv surveyed individuals across eight countries between mid-March to April 19 2020 (N=66,266)[66]. They found that the perception of individual threat of COVID-19 was the highest in Italy, followed by the UK, Spain and others with Germany being the lowest. The authors note that the perceived threat was also in relation to the phase of the outbreak with Italy and UK, two of the most affected countries in Europe. They also found that the level of threat was related to the trust in government and health care systems, which were high in Germany, we return to socio-political systems later.

Perceived proximity to the outbreak also played a role. During the H1N1 2009 pandemic, individuals assumed they had lower risk if they had a higher perceived health status or that they perceived the outbreak was outside of their proximity[67]. Proximity is often evaluated by individuals in terms of geographical distance, but also own perceived differences in their own living environment. Another common belief found in studies in the UK, US, New Zealand

and Australia in relation to previous pandemics was that geographical proximity was protective and that respiratory viruses were unlikely in a 'modern, developed country' and hence a perceived lack of urgent risk and lag in adopting public health messages[68, 69, 70]. A study in the UK about public attitudes surrounding H1N1 found that individuals believed that respiratory viruses were only more likely to emerge in 'other' living environments such as those with low hygiene levels, high population density, poor border control and health systems[71]. Some, however, related the high ability and propensity for viruses to spread worldwide more rapidly due to air travel.

Distancing is a typical way of dealing with the negative impact of health risks by using what is characterized in the literature as 'othering'[72]. Othering refers to blaming or differentiating oneself from 'the other', which in turn denies personal risk. During H1N1, but also repeated with COVID-19, was the designation of a vulnerable group of 'others' that needed to be shielded and were perceived to be at a higher risk of infection. This included those with chronic health problems, impaired immune systems (e.g., undergoing cancer treatment) or in frontline occupations (e.g., teachers, health workers). Although the literature on this point is largely from the H1N1 pandemic, it appears to echo similar experiences in the COVID-19 pandemic. A general narrative in this literature is the public belief that 'it won't happen to me' and have an inability to rationally evaluate the individual risk of infection while also actively distancing themselves from the threat by clarifying their difference to 'other' groups and circumstances that would have a higher risk of infection. We discuss the link of othering with potential discrimination later in Section 3.5 on individual and group differences.

4.4 Previous national experience with pandemics, socio-political systems and trust in government and science

There is a strong national variation in the acceptance and usage of face masks, which has been attributed to several key factors. These are: (i) previous experience with viral infections (e.g., SARS, H1N1), (ii) normalisation and history of mask wearing for other reasons (e.g., pollution) and rapid adoption for those without a face mask history; and, (iii) socio-political systems, linked to individualistic versus socially cohesive structures, political polarization and trust in government.

Previous experience with viral infections such as SARS and H1N1 is linked to more universal and early mask use and acceptance during COVID-19[73]. In addition to face mask policies, these countries also simultaneously introduced a battery of other interrelated non-pharmaceutical interventions. After SARS, most governments from the nations that were deeply influenced had already set up rapid responses and policies that would allow them to react swiftly in the event of another respiratory pandemic[74]. In many Asian countries impacted by SARS, broad communications had already previously been tested and put in place, such as media messaging and billboards showing how to wash hands and wear masks properly[75]. At the start of SARS 65% of respondents in Hong Kong said they wore a mask[76]. Singapore, for instance had previously distributed over 1 million 'SARS toolkits' which included a digital thermometer, two surgical masks and instructions in four languages[77]. They had also previously developed random and electronic monitoring of compliance. After the first COVID-19 case was reported in Singapore on January 22, 2020, the country introduced deep and swift measures by February 7 2020. All non-essential gatherings were cancelled; daily temperature and health checks were performed in schools and workplaces, and face mask wearing and physical distancing were quickly advised in public places. So deep was the intervention that an unintended consequence was that influenza levels declined steeply from a mean of 57.3% (first 6 weeks of 2020) to 3.5% (week 14), lower than any influenza levels for the past 3 years[78]. The authors attributed this to the introduction of wide and deep non-pharmaceutical interventions, which included face masks in addition to the suspension of mass gatherings, social distancing and public promotion of the social responsibility to stay at home.

Second, in nations where individuals have previously worn face masks for other reasons such as pollution (e.g., India, China), there is higher and more normalized compliance (see previous section on international policies). There is limited knowledge of face mask wearing in countries without a previous history, but an initial study demonstrated that face mask adoption could happen rapidly[79], which we discuss in more detail later in this report.

A third more heterogeneous strand of literature focuses on socio-political systems, linked to individualistic versus socially cohesive structures, political polarization and trust in government. One body of research draws from research on socio-political systems that compare more community-based social cohesion versus those from more individualistic based structures[80]. This has been posited in the form of 'tight versus loose cultures', with countries such as the US, Italy and Brazil positioned as having the weakest social norms and being more permissive[81]. These socio-political structures have in turn been linked to the ability to engage in coordinated action.

This strand of literature currently exists largely in pre-print non-peer reviewed format due to the slower publication processes within the social sciences, noted previously. It examines the inability for coordinated action due to political polarization – which is notable in countries such as the

US, UK and Brazil, which in turn results in distrust of the opposing party and beliefs in false information that can undermine public health messages. Using geolocation data of daily movements from January until April 23 2020 from around 35 million unique devices and debit card transaction data of over 12 million cards in the same period in the US, one study found that residents in Republican voting counties were less likely to stay at home after a state order[82]. Conversely, those from Democrat counties were more likely to switch to online e-commerce spending after stay at home state orders were implemented. Adherence was also related to the political affiliation of the governor and suggested that bipartisan support was essential to maximize the effectiveness of policies. We note some concerns with these ecological studies using political variables as there are very likely many other confounders that play a role.

Another medRxiv pre-print examining the level of confidence in local and national health care systems and governments and the WHO during COVID-19 found individuals reported the lowest levels in the UK and US across all institutions compared to other countries such as Spain, the Netherlands, Italy and Germany[83]. Another study drawn from two MTurk studies of US respondents (N=1153) found that political conservatism predicted lower compliance with social distancing[84]. They found that the politicization of COVID-19 prompted conservatives to discount mainstream media reports of the severity of the virus, leading them to downplay the health risks and adhere less to social distancing protocols, also when controlling for key demographic and psychological variables. As demonstrated in more general research, the result can be echo chambers and less cross-group information sharing[85]. These more narrowing lines of information can be amplified by social media streams.

Another pre-print non-peer reviewed study examined trust in science and government during the COVID-19 and the relationship with compliance with public health measures[86]. Using digital trace data from Twitter and survey data collected online via Telegram and Facebook, they examined the evolution of trust in science in Italy during early phases of COVID-19. They found that there was an initial reliance on information seeking from scientists and public-health authorities. Trust in science and institutions (local or national government) emerged as a consistent predictor of both knowledge about COVID-19 and adherence to non-pharmaceutical measures. As the epidemic peaked in Italy, however, they found a reverse in information seeking and trust in science and health authorities, interpreted by the authors as an erosion of trust. Interestingly, using an experiment they found that those who held incorrect information about COVID-19 gave no or even lower importance to scientific information about the virus. Many disadvantaged communities and particularly racial and ethnic minorities hold a low level of trust in public institutions due to persistent experiences of discrimination[87], with particularly low levels of trust in the health care system[88].

4.5 Individual characteristics: Vulnerability, compliance and discrimination

There has also been attention to the study of differences in the vulnerability and adoption of non-pharmaceutical interventions across groups. This work can largely be divided into topics examining: (i) face mask usage in relation to vulnerable groups more likely to die if infected, (ii) difference between demographic groups in relation to asymptomatic infection and compliance to non-pharmaceutical interventions such as face masks; (iii) additional traits such as personality or physical traits (e.g., eye-glass wearing, activity level) that make it more difficult to wear a mask; and, (iv) discrimination or social reactions to mask wearing.

Throughout previous pandemics and with COVID-19 there has been a focus on vulnerable groups more prone to infection and death from the virus. A considerable amount of COVID-19 research has focussed on differences in death rates due to individual characteristics such as age[89] or other vulnerabilities related to co-morbidities (hypertension, obesity, diabetes)[90], being male, from certain ethnic groups (African, Asian) or working in front-line occupations[91]. Some of these factors are related to deprivation such as some groups are more likely to become infected since they are more often key workers (e.g., bus drivers, care), rely on public transport or have poor or no internet contact, putting them at a higher risk of leaving the household and higher risks of contact[92]. Here policies have been effective in promoting the wearing of face masks for protection around those who are ill, with the majority within health care settings. Several studies conducted in relation to H1N1 and during SARS, concluded that the perceived need or wish to care for sick (isolated) loved ones overrode concerns about self-protection and personal distancing. A Canadian study of SARS reported that although compliance with the quarantine order was high, within house protocols such as mask wearing were uneven and often ignored when a family member was sick and required care[93].

Another emerging area of COVID-19 research is the study of how compliance to non-pharmaceutical interventions such as wearing face masks varies across socio-demographic groups and first particularly age groups. Representative data measuring health behaviour across eight countries (Belgium, France, Germany, Italy, the Netherlands, Spain, UK, US) published in a medRxiv non-peer reviewed pre-print discussed previously, found that younger people perceived the COVID-19 threat lower to themselves than

older groups, also related to lower adherence to non-pharmaceutical behaviours[94]. Mask wearing was the highest in older 65+ age groups in all nations except the UK and the Netherlands where mask wearing was both low but also more evenly enacted across age groups. In the UK, the only clear differences in these behaviours across age groups were higher levels of hand sanitizer use by the youngest groups (18-24) and the avoidance of public transportation by the oldest groups (65+). Conversely, a medRxiv non-peer reviewed pre-print study by Goldstein and Lipsitch[95] examining weekly COVID-19 cases in Germany found that the incidence of infection increased the strongest amongst younger age groups between the starts and end of March. These relative increases were found for all individuals under 35, but were especially large amongst those between 20 and 25 (RR=1.4; 95% CI: 1.27-1.55). The authors suggest that increased mixing and lower adherence of social distancing practices amongst these age groups could be responsible for this relative increase.

This representative data also found particularly important differences by sex[96]. Women exhibited substantially higher perceptions of threat compared to men, which translated into the adoption of a wider-range of preventive behaviours. They conclude that one of the most protective factors for women during COVID-19 has been their adoption of multiple protective interventions. Women were more likely to wear face masks across the nations that were examined with the exception of the UK and the Netherlands where face mask wearing was similar across the sexes. In spite of the fact that the case fatality rate for COVID-19 has been shown as substantially higher for men[97], this does not translate into higher perceptions of threat or related behavioural protection, suggesting a need to target this and other groups for future communication campaigns.

Some early psychological literature published mainly in pre-print non-peer reviewed literature has examined psychological factors related to face mask wearing. Given that these are non peer-reviewed pre-prints, the selectivity of respondents, small sample size and often-artificial experimental circumstances in which the research was carried out, replication would be necessary before using this as evidence to draw firm conclusions (see Appendix 5). A pre-print study asked 86 participants to assess how they felt wearing a mask while being exposed to groups with different levels of mask wearing[98]. Exposure to social groups where more wore a mask reduced the strange feeling of wearing a mask, suggesting that as mask-wearing is easier when a larger majority of society also wears a mask. Another non-peer reviewed PsyArXiv preprint engaged in an internet-based study (N=457) using 'human-like' characters wearing a mask or exhibiting different facial expressions (neutral, happy, angry). They found that reports of interpersonal distancing were reduced when the character was wearing a face-mask as they were perceived as more trustworthy.

Historical reports from the bubonic plague through to HIV and COVID-19 have reported a rise in violence and discrimination against stigmatized groups that carry a disease[99]. Early in the COVID-19 period there is anecdotal evidence of anti-Asian discrimination in some areas[100], with a PsyArXiv preprint reporting stigma faced by the Chinese community outside of China due to wearing face masks, particularly in countries such as the United Kingdom that did not adopt early face mask policies[101]. During the SARS pandemic, chronic kidney disease patients in Hong Kong were perceived by the public as high risk 'super spreaders' of infection. The study concluded that this potentially stigmatized group wore masks as a symbol of socially responsible action, but also to protect themselves during the pandemic[102]. Another strand of the literature has found that interventions such as frequent hand-washing or mask-wearing has the potential to attract social stigma, embarrassment or discrimination. Face mask wearing was found in some studies as problematic since some were concerned that it would make others see them as indicating infection. This was the case in a study of face mask wearing within a Hispanic community in the United States[103].

4.6 Perceived barriers: supply concerns, resource constraints and comfort

Another segment of the literature from this review looked at the key barriers to face mask usage by the general public, which were identified primarily as: (i) supply concerns and inability to source them, (ii) resource constraints, (iii) concerns about comfort, appropriate fit and incorrect usage; and, (iv) environmental waste.

A recurrent theme in the literature were shortages of protective equipment, including face masks. A considerable amount of the face mask literature in this systematic review related to the shortage or lack of supply of face masks and PPE, particularly for health workers[104, 105, 106]. During SARS, the lack of protective equipment and especially masks led to a 'state of panic' in Taiwan[107]. So great was the shortage during SARS that the Japanese government donated thousands of masks and other protective equipment to Vietnam and in Toronto, Canadian doctors sought to purchase their own supplies[108]. The extreme shortage of PPE was a strong theme from previous epidemics such as SARS, where lack of worldwide protective masks, gloves and respirators was positioned as the one of the key 'lessons learned'[109]. This worldwide shortage of masks and other PPE, however, repeated itself once again with COVID-19 in many countries.

The absence of clear agreed standards for making and manufacturing face coverings is also lacking. Since manufacturing issues have shown to play a role in the provision of PPE, clear guidelines for manufacturers and those making masks at home is essential. Information needs to be provided to produce coverings that reach the proper standards, such as the higher efficacy multi-layer hybrid masks discussed in Section 2.7. The CDC in the US for instance, provides a very clear tutorial on how to make a face mask at home and information about washing, re-use and how to wear face coverings.

A shortage of face masks and protective equipment for medical staff also produced a feeling amongst the public that face masks were unavailable or that wearing face masks would unduly compete with medical resources. There were also cases of face masks and other PPE that had been imported from other countries as being 'recalled' which may have impacted public trust. An international poll of face mask wearing during COVID-19 from March 12 to April 12 across 15 countries, reported that the largest perceived drawback in wearing face masks in most countries was getting access to one[110]. Specifically they responded to the question 'even if I wanted to wear a face mask, I have heard they are not available anywhere or are too expensive'. This was the highest in Japan (57%), France (49%), Germany and Spain (45%) and the UK (42%). A systematic review demonstrated that negative emotions such as fear can lead to a change in behaviour only if people feel that they are able to control the threat. If they cannot – such as facemask regulations without a clear supply of access to facemasks – reactions will be defensive due to feelings of helplessness[111]. Fear is thus only effective when individuals feel a strong ability or level of efficacy, otherwise it will elicit a defensive and negative response.

One of the greatest risks of virus spread is the inability of some individuals to adopt policy recommendations due to resource constraints such as money to buy or ability to make their own face covering. The Italian government for instance, set the price of surgical masks to a maximum of 50 cents to assuage this problem[112]. Some community members may lack the resources to purchase or make face masks but also live in areas with high neighbourhood density or lack the ability to social distance. A variety of studies conducted during previous pandemics in the UK and US, found that perceived obstacles for following isolation, distancing and other measures were related to the economic pressures to continue to work and fulfilling familial and workplace commitments[113]. A study of H1N1 in 2009 in the UK reported incidences of individuals breaking compliance such as isolation due to boredom, job security and economic strain[114]. A repeated fear in the US literature was shutting down the economy and ability to financially survive in the household when schools were closed or individuals were unable to work[115]. Translating these findings to face masks, it seems paramount to ensure broader access for those unable to purchase or make face coverings, such as cutting costs or free distribution to certain groups.

Multiple studies concluded that compliance with wearing masks for a longer period of time was hindered due to the fact that they were uncomfortable[116]. A dearth of literature has examined this in the health care setting, including sores and headaches due to long periods of wearing[117], which we do not cover in this review. A block randomized study of mask-wearing in the United States isolated three main issues related to the comfort of mask wearing in the home[118]. First, the level of intensity or physical exertion impacted comfort and compliance. Second, environmental factors were key such as temperature, ventilation and apartment size. Finally, the mask fit was key which was variable depending on whether they had eye glasses and the facial structure of respondents namely high/low cheekbones, bridge of the nose and shape of the face. Those with low cheekbones and small nose bridges had difficulties in mask wearing due to the need to constantly adjust the mask. Others noted difficulties due to heat and dampness after wearing it or having eyeglasses. The authors also noted that young children persistently touched and grabbed their mother's mask. It should be noted that this study examined surgical masks only (which have less ventilation) and not cloth masks (see Box 1). Although there are fewer community studies of face mask wearing, appropriate fit appears to be key to avoid adjusting or removing the mask. Finally, there has been the additional concern largely voiced outside of academic publications that particularly if disposal masks were to be used there would be considerable environmental waste.

5. Public adherence to face mask and coverings, relationship with other interventions and importance of clear and consistent public messaging

A central question asked by many governments without a previous history of face mask or covering wearing is: (i) whether their populations would actually adopt this more invasive behaviour; and, (ii) how face mask wearing compares to and is related to other non-pharmaceutical interventions. After exploring this, we then describe the importance of clear and consistent public messaging, focusing on an example in the UK.

5.1 Adherence to face mask wearing: a cross-national comparison

We were able to locate results from two cross-national representative surveys, which at the time of writing are pre-prints and not peer-reviewed publications but provide

a cross-national comparison of face mask and covering wearing from mid-March to mid-April 2020. It is vital to note that respondents in these studies were asked about wearing a face mask due to COVID-19 between mid-March to mid-April 2020 and that countries were all on different disease trajectories, with varying and changing policy recommendations during this period. The most comprehensive study is a representative survey measuring health behaviour carried out by the Max Planck Institute for Demographic Research between March 13 to April 19 2020 (N=66,266) across eight countries (Belgium, France, Germany, Italy, the Netherlands, Spain, UK, US). It is published as a medRxiv non-peer reviewed pre-print that examines attitudes and behaviours surrounding COVID-19 including face mask wearing and other non-pharmaceutical measures[119]. They found that the wearing of a face mask substantially increased over time (all $p < 0.001$, exception the Netherlands, Belgium) (see Figure 4 for results of final week of study). Sharp increases of mask wearing of the general population were observed in Italy (to above 80%), Spain (above 65%), and the US (above 70%). Levels of face mask usage in France and Belgium in that period rose to around 40%. The UK and the Netherlands had the lowest reported levels of face mask wearing, though the UK still had increases in reported face mask wearing to over 20% by April 19. This was in addition to hand hygiene increases particularly in the UK, Germany, Italy and the US. Focussing on the UK, the study found that behaviours that were the most adopted in this period was the reduced use of transportation ($p < 0.001$) and a sharp increase in social distancing ($p < 0.001$).

Another survey poll conducted by IPSOS in 15 countries between March 12 to April 12 of around 2,000 persons per county (N=29,000) also found cross-national variation in the wearing of face masks to protect against COVID-19[120]. Wearing face masks for protection was at very high levels in Vietnam (91%), China (83%), Japan (77%) and India (76%), which were relatively stable over the one month period. Like the previous study, Italy (81%) and Spain (62%) showed the highest levels of adopting mask wearing, likely also reflected by the relatively earlier onset and outbreak in those nations. Lower levels were reported in that period in France (34%), Canada (28%), Australia (21%), Germany 20%) and the United Kingdom (16%). The United States had a sharp increase from 11% March 12-14 to 50% within one month by April 9-12, likely related to the policy change discussed previously of face coverings in public by the CDC on April 3 2020[121]. Notably, a PsyArXiv non-peer reviewed pre-print was able to use this policy introduction as a natural experiment to demonstrate the impact of the CDC's recommendation on reported mask wearing and buying[122]. Using a large nationally-representative survey across the US (N=3,933) that was in the field, they found significant increases in mask wearing (+12 percentage points) and buying (+7 points) which they concluded demonstrates the speed at which this behaviour can be adopted by the population and the importance of national leadership and clear communication.

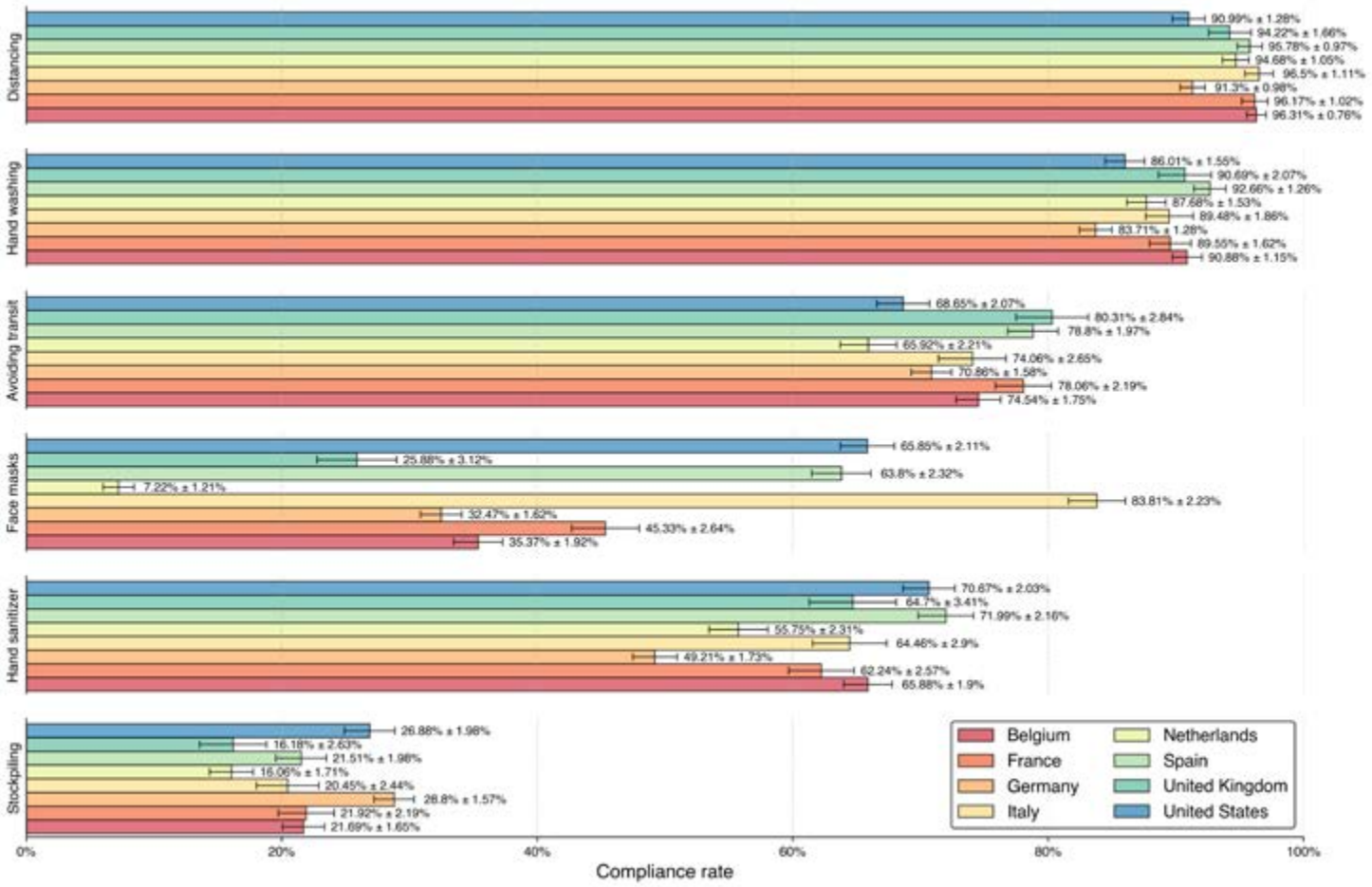
5.2 Adherence to other non-pharmaceutical interventions: face masks and coverings in perspective

We also examined variation in the adherence to a variety of non-pharmaceutical interventions to put face mask and covering wearing in perspective. Here we can draw from the recent cross-national COVID-19 study on reported behaviours mentioned in the previous section[123]. Here a hierarchy of adherence to non-pharmaceutical interventions emerges during COVID-19, which is shown in Figure 4. A strong caveat, however, is that interventions are rarely introduced or judged alone but rather as packages, discussed in more detail in the conclusion. For comparison, we also examined nine studies mostly of nationally representative samples covering a range of outbreaks in the US (see Appendix 3, Additional Results, Figure A3.1)

There was virtually universal enactment of avoiding public transportation and social distancing, which was the highest across all countries. This was followed by very high levels of hand-washing, the highest in the UK which reflects a very strong and clear campaign. This COVID-19 behaviour is in line with previous research examining the H1N1 pandemic and SARS who found individuals were very familiar with hand and respiratory hygiene behaviour (e.g., hand washing, cough/sneeze etiquette). This in turn meant that they perceived them as acceptable and common-sense behaviour they could easily adopt to reduce infection transmission[124]. The next type of behaviour was the use of alcohol-based hand sanitizers, which has considerable cross national variation which may be related to lack of supply. Wearing face masks was also at very high levels in many countries by the third week in April 2020. There was scepticism in the media and by some governments that public without previous experience of wearing face masks and coverings would not comply, yet as Figure 4 shows, self-reported uptake relatively high in most countries, reaching particularly high levels in Italy (83.8%), the US (65.8%) and Spain (63.8%). It remained very low, however, in the UK at 25.9% and the Netherlands at just 7.2%. Appendix 3 also shows compliance to other interventions such as avoidance of suspected infected people, avoiding touching eyes, nose and mouth, stopping close contact (shaking hands, hugging) and avoiding public events, crowds and cancelling social plans.

FIGURE 4

Percentage of individuals who reported having adopted specific behaviours in response to COVID-19, 3rd week in April 2020 by country.



Source:Perrotta *et al.* (2020)156, we are grateful that they shared raw data & detailed information. Bar charts show median values and 95% CI as errors.

5.3 Package policies: face mask usage, physical distancing rules and hand sanitizer

As noted previously, when countries introduce non-pharmaceutical interventions, they often work concurrently to reduce infection transmission. Measures are rarely introduced as individual interventions, but rather as a 'package' including distance, masks and hand hygiene. Due to the introduction of often multiple interventions at one time and varying levels and progression of the virus outbreak across regions, it is difficult – or arguably impossible – to evaluate the effectiveness of one sole intervention.

A persistent question has been the relationship of face mask wearing to other behaviours such as social distancing or disinfection, which is difficult to definitely determine for the reasons argued above. A large meta-analysis published on June 1 2020 in the Lancet linked various interventions including face masks, eye protection and social distancing[125]. They concluded that the risk of being infected was 13% within one metre and 3% beyond that distance. They reported that for every extra metre of distance of up to three meters, the risk is further reduced by half. Wearing a face mask and eye protection were found to significantly reduce risk of infection, with the duration and intensity of contact likewise key factors. We note, however, that this study had several problems and cannot be directly translated to mask wearing in the general public and was therefore, for instance, not included in previous advice for the general public provided by DELVE[126]. Reasons include the fact that the bulk of the data focussed on MERS and SARS (and not COVID-19), that most studies were conducted in healthcare settings (i.e., not wearing in the public), and that the focus was thus more on protection of the wearer than source protection (i.e., preventing transmission from the person wearing the mask). Some of the studies that had no infections in either the masked or unmasked groups

were not scored, which biased towards the benefit of mask wearing. There are also concerns about the study of the relationship between distance and risk, which is based on extrapolations and the assumption of a linear relationship between distance and risk (whereas it is likely exponential). We note therefore, concerns about the conclusions of this study and particularly those related to distancing.

At the time of writing in late June 2020, governments across the world had different rules regarding social distancing and were examining whether other non-pharmaceutical interventions would be effective in reducing those levels. At the time of writing, countries with the largest distance of 2 metres (6.5 feet) are Canada, Spain and the UK. The US has 1.8 metres, Germany and Australia 1.5, whereas the WHO, China and France all suggest a 1 metre (3.3 feet) distance. In England, the government previously advised to: "Keep your distance if you go out - 2 metres apart where possible". In the COVID-19 guidance for employers and employees, the Department of Business notes: "Maintain two-metre social distancing, where possible" and "Where possible, you should maintain two metres between people… Where it's not possible for people to be two metres apart, you should do everything practical to manage the transmission risk." On June 23 2020, this was updated with the announcement that as of July 4 2020, the government suggests where it is not possible to stay two metres apart, guidance will allow people to keep a social distance of 'one metre plus', with plus seeming to suggest some sort of additional mitigation[127].

In response to easing the lockdown, countries such as South Korea and Portugal maintained the 2 metre distance where possible, but then clarified the etiquette of combining different types of interventions (hand sanitizer, mask use) when the 2 metre rule was not possible. In South Korea, the advice is to maintain the 2 metre guideline (or 'two arms lengths') in general, which is relaxed to one metre inside shops, restaurants and cafes. As of June 01 2020 in Portugal, the 2 metre rule was suggested where possible. In Japan, the '3C' rule has been implemented, which is to avoid crowded places, closed spaces with poor ventilation and close contact, all with wearing a face mask where possible. The emphasis has been less on rules and more on understanding how to avoid the transmission of droplets from one household to another, such as through social bubbles and tight networks[128]. Distance is often not addressed in exclusion, but as a policy package of almost universal use of hand sanitizer when entering (shops, restaurants) and demanding that face masks are worn inside shops. There is also education about etiquette in places like restaurants, with sanitizers at tables, all staff wearing masks, instructions to take off masks when sitting and putting it on when going to the washroom. At the moment Canada is also moving towards a policy across different provinces that combines face masks with a reduction of the 2 metre 'hockey-stick' rule. Health Canada now recommends that people wear cloth masks when social distancing of 2 metres is not possible, particularly in crowded public settings, such as stores, shopping areas and public transportation.

5.4 The importance of communications, clear and consistent public messaging

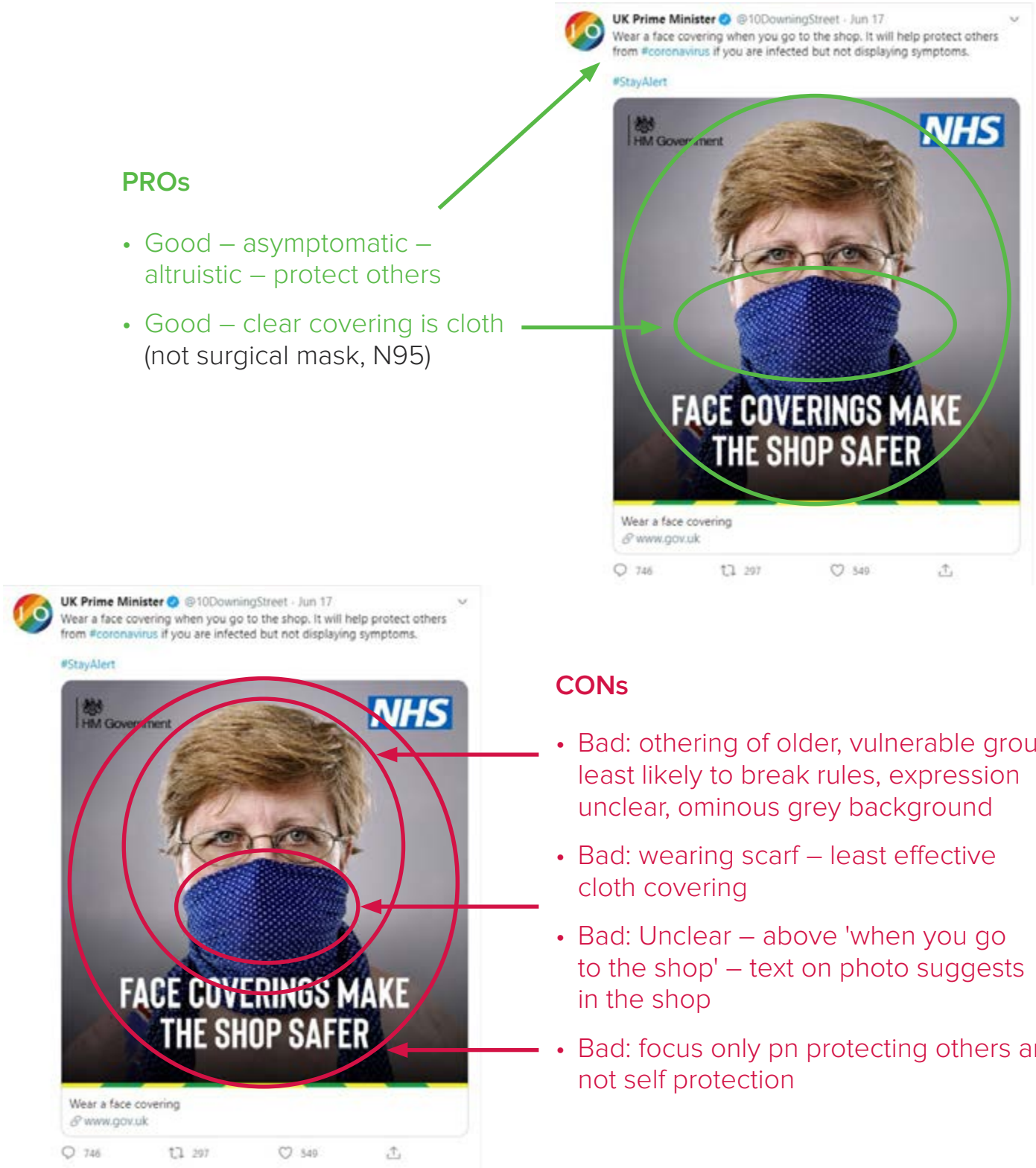
This review of the behavioural literature on face masks and coverings also revealed the importance of communications and public messaging during pandemic outbreaks on the effective implementation of and adherence to face mask and other non-pharmaceutical interventions (see e.g., Figure 5). A study of non-pharmaceutical interventions in Canada during the SARS outbreak found that inconsistent information from various sources prompted individuals to question the credibility of available information[129]. This inconsistent information resulted in fear and denial of the pandemic. Many participants in the study expressed doubts about the information from the public health department, which in turn influenced their level of perceived risk. For example, there were mixed messages about who needed to quarantined, with some members of the household asked to be quarantined whereas others were not.

Figure 5 also provides a recent example of mixed messaging that might be confusing to the public and contradicts some of the knowledge in this report. The top panel shows some positive aspects of the messaging such as clarifying that it is an altruistic behaviour to protect others and face coverings can be worn. It however engages in othering of a vulnerable group who is the least likely to break rules (and be symptomatic), does not focus on self protection and now as we explore in the next section shows the least protective and non-recommended item - a scarf.

Literature examining the H1N1 2009 pandemic in the UK and Spain concluded that the public became sceptical about the way in which the communication about this new respiratory infection was presented, particularly by the media. They found the communications to be unreliable, premature, inconsistent, sensationalist and unduly alarmist. Several UK studies reported scepticism from individuals due their perception of the media's propensity to create hype and panic in what they viewed as an attempt to scare people[130, 131]. A Spanish study of H1N1 likewise concluded that reporting was at first sensationalist, followed by contradictory advice coming from their own Spanish politicians and officials versus other international leaders[132]. Doubts about the trustworthiness of information and a general information fatigue were related to people disregarding advice in New Zealand and the UK in

FIGURE 5

Example of public messaging about face coverings, UK Government, 27 June 2020.



Note: Full text above reads 'Wear a face covering when you go to the shop. It will help protect others from #coronavirus if you are infected but not displaying symptoms."

Source:Twitter, UK Prime Minister @10Downing Street, June 17 (accessed 17 June 2020).

relation to H1N1 [133, 134]. Another reason for scepticism about the information was related to mixed messages in the media and feeling that it was difficult to sift between facts and opinions.

As many governments that lacked experience from SARS and previous outbreaks, the WHO, the most trusted global supranational organisation for health advice, has changed positions on face mask use and wearing for the general public between early April 2020[135] and revised in June 2020[136]. This likely initiating a repeat of some of the public's previous reaction to changing information about SARS and H1N1. As the initial section on international policies on face masks has shown, nations and even states, countries or regions within these have adopted different face mask policies. As noted previously, this has been the case with Scotland, Wales and England.

"Three main factors stand in the way of prevention: First, public indifference. People do not appreciate the risks they run. The second factor.....is the personal character of the measures which must be employed...It does not lie in human nature for a man who thinks he has only a slight cold to shut himself up in rigid isolation... Third, the highly infectious nature of the respiratory infections adds to the difficulty of their control."

Major George A Soper, 1919, *The Lessons of the Pandemic*, Science[157]

6. Conclusion

This report provides evidence on the main policy directives of face masks in the international sphere in addition to the core factors related to the adherence of wearing a face mask and covering. We found many similarities across previous pandemics and 'lessons learned' that appeared to repeat themselves from the Spanish flu through to SARS, MERS, H1N1 to COVID-19. It was clear that core socio-behavioural factors were pivotal such as the public's understanding of the virus, risk perception, previous experience with mask wearing and socio-political systems, individual characteristics and perceived barriers. We likewise found importance in consistent and clear public messaging; including adopting a package of policies and that countries without a previous history of mask wearing did indeed adopt this behaviour. Finally, we produced evidence showing that cotton face coverings can provide significant protection against the transmission of aerosol particles.

The key points from this report are:

- Cloth face coverings are effective in reducing source virus transmission, i.e., outward protection of others, when they are of optimal material and construction (high grade cotton, hybrid and multilayer) and fitted correctly and for source protection of the wearer
- Socio-behavioural factors are vital to understanding public adherence to wearing face masks and coverings, including public understanding of virus transmission, risk perception, trust, altruism, individual traits, perceived barriers
- Face masks and coverings cannot be seen in isolation but are part of 'policy packages' and it is imperative to review interrelated non-pharmaceutical interventions in tandem including hand hygiene, sanitizers and social distancing when maintaining the 2 metre or 1 metre+ distancing rule is not possible
- Consistent and effective public messaging is vital to public adherence of wearing face masks and coverings. Conflicting policy advice generates confusion and lack of compliance. Populations without a previous history of mask wearing have rapidly adopted face coverings during the COVID-19 period.

This report provides scientific evidence in which experts and governments can inform their decision-making but does not extend to direct policy directives. As noted in the disclaimer and elsewhere[137], but also in our GRADE recommendations (Appendix 5), research and policy-making in this area is ongoing and continuously under revision. We do note however, that the current advice in England regarding non-surgical face coverings for the general public, employers and employees does not align with the broader science evidence in this report. For example, COVID-19 secure guidance for businesses and staff issued by HM Government on June 14 2020[138] states (see Appendix 4 for entire text, emphasis added by authors):

"There are some circumstances when wearing a face covering may be marginally beneficial as a precautionary measure. The evidence suggests that wearing a face covering does not protect you, but it may protect others if you are infected but have not developed symptoms...

It is important to know that the evidence of the benefit of using a face covering to protect others is weak and the effect is likely to be small, therefore face coverings are not a replacement for the other ways of managing risk, including minimising time spent in contact, using fixed teams and partnering for close-up work, and increasing hand and surface washing."

We note that although evidence is mentioned, there is no clear reference to the specific material.

We also note that particularly in relation to face masks and coverings, there has been a particular precaution in some contexts such as England, that seems to override the scientific evidence and lack transparency in decision-making[139, 140]. It may be attributed to several factors. First, in the face mask and covering sphere, there has been a focus on highlighting very small fragmented pieces of knowledge and assertion that evidence was not strong due to the lack of clear RCT[141]. As noted previously, there have also been no clinical trials of coughing into your elbow, social distancing and quarantine, yet these measures are seen by the public and policy-makers as common sense and have been widely adopted and are considered as effective. The heterogeneity of the research designs does not fit the standard RCT evidence-based medicine approach[142], yet there are still many high quality studies (see Appendix 5). A non-peer reviewed medRxiv pre-print of a systematic review of facemasks likewise concluded that RCTs "may not be the best quality evidence to evaluate a population behaviour like facemask use that is likely to be imperfectly implemented". They conclude that "compared to RCTs, observational data (cohort and case-control studies) may give superior quality evidence for efficacy of facemask wearing to avoid influenza-like-illness, given they are trying to relate actual behaviour to outcomes"[143]. Another non-peer reviewed pre-print study released on 23 June 2020 linked the face mask wearing rate to country's COVID-19 death rates[144]. As we note, however, throughout this report although there may be a correlation, it is likely never one policy in isolation and rather a combined layering or package of policy effects. Second, the lack of decisive measures and changing positions on face masks and coverings for the general public by the WHO and some governments has undoubtably fuelled this uncertainty about their effectiveness. Third, an additional debate has been about the applicability of results across multiple settings (e.g., health care versus in the community), pandemics (e.g., can SARS research be relevant for COVID-19) and cross-national differences. We note that although there are core differences, there can be many standard 'lessons learned' from previous and other experiences that appear to be repeating themselves. Finally, recommendations and guidelines often either implicitly or explicitly considered supply issues and concerns about access and competition of the public taking away vital PPE equipment of surgical masks. This is a logistical and supply issue and not an issue about the effectiveness of face masks and coverings.

We note various limitations of our work and provide an attempt to scrutinize and GRADE[145] our report in relation to the quality of the evidence (Appendix 5). The vast literature review also covered non-COVID-19 studies and different nations, which although had the strength of breadth, ignored intricate differences. We also note that although we report cloth face coverings to be effective, the meta-analysis was in a health care setting and the fabric tested within a laboratory, but evidence was supplemented from observational studies[146]. Further testing in community settings would be desirable. Few RCTs have been conducted to examine the effectiveness of different types of face masks and coverings. But as noted throughout this report, in addition to ethical concerns, this seems highly unrealistic to devise such a study, particularly in current circumstances.

Appendix 1. International policies on facemask requirements and recommendations

TABLE A1.1

Type of requirement by number of countries (as of June 15 2020)

General category	Total countries	Detailed categories	Total countries
Indoor public places	15	All commercial establishments	1
		All indoor public places	10
		All indoor public places and outdoor within 20 meters of others	1
		All indoor public places with multiple people	2
		Supermarkets, banks and some indoor spaces	1
Everywhere in public	71	Everywhere in public	71
Certain public places	9	Certain public places	1
		Everywhere in public (major cities)	1
		Everywhere in public where social distancing isn't possible	6
		Public roads and business employees	1
Public transport only	7	Public transport only	7
Public transport and crowded places	12	Public transport and schools	1
		Public transport and shopping	1
		Public transport and stores	2
		Public transport + everywhere in public where social distancing isn't possible	1
		Public transport + everywhere in public with more than 10 people	1
		Public transport + markets + most public places	1
		Public transport + select states: everywhere	1
		Public transport + shopping	2
		Public transport + shops	1
		Public transport, markets, supermarkets & crowded places	1
Universal mask usage	6	Universal mask usage	6
Total countries information available* **	**120**		**120**

Source: Masks4all data158; general categories created by authors. Note: ***This information is only available for 120 countries.

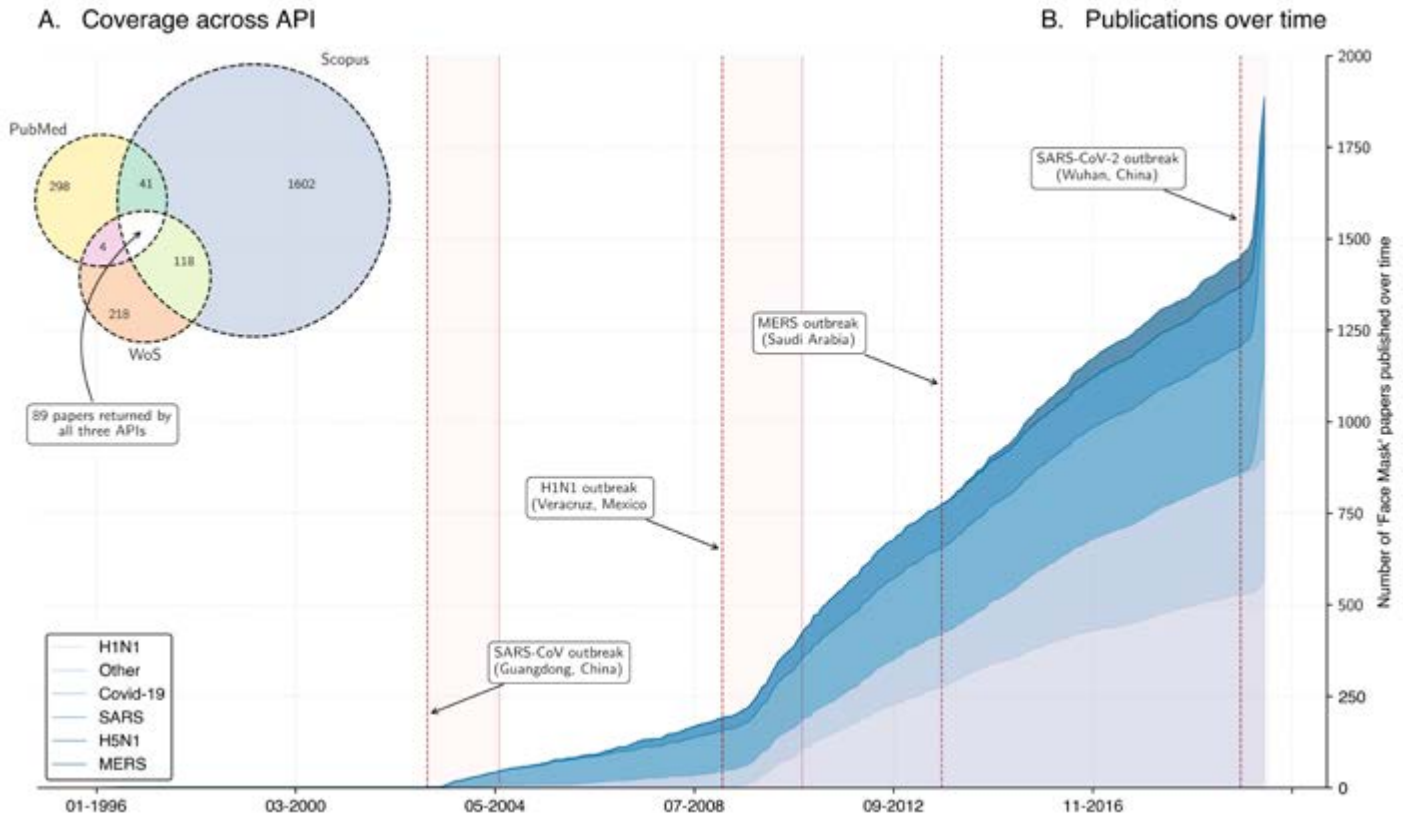
Appendix 2. Data and Methods

A2.1 Further information systematic review study selection

Figure A2.1 provides a detailed illustration of study selection and the period of the aforementioned previous respiratory outbreaks. After duplicates were removed and selection criteria was enacted, we produced a harmonized file. The majority of the studies (561) on aggregate are returned from queries relating to H1N1, but for the year of 2020, it is naturally COVID-19 (263 in 6-months to date). In this rapid policy response brief that needed to be produced very quickly, we do not provide details of all study selection and exclusion, but will do so in a more detailed future publication. Briefly, we identified and excluded duplicate articles and studies that did not include humans. We included all studies that were returned from three leading bibliographic databases (Scopus, PubMed and Web of Science). Due to the rapid shifts in knowledge surrounding COVID-19 and longer publication time for most behavioural and social science journals, we also included some pre-print non-peer reviewed articles from SocRxiv, PsyRxiv, MedRxiv, bioRxiv and SSRN and indicate this when evidence is provided. There was no selection on language but the majority of articles are in English. We included all research designs, with the exception of the meta-analysis, discussed in detail in relation to that analysis.

FIGURE A2.1

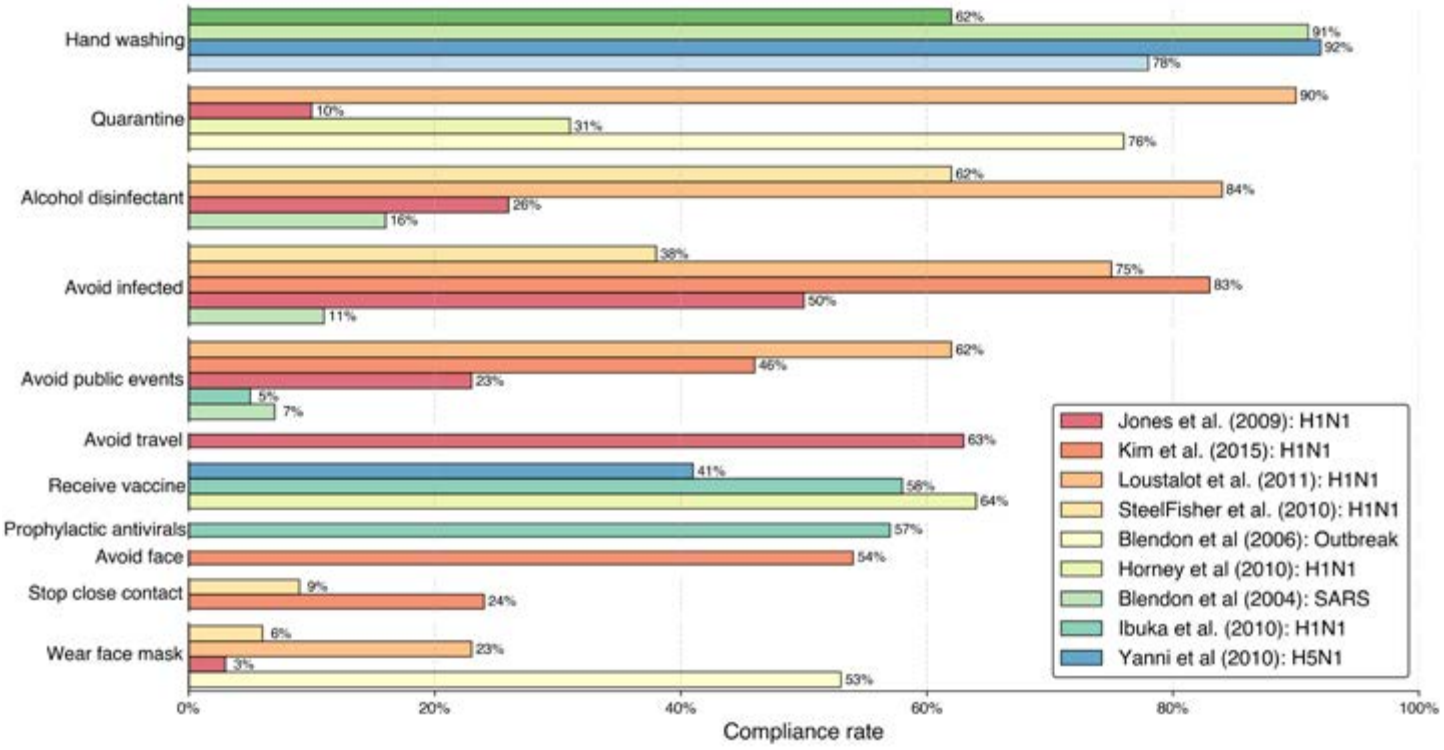
Contents of the systematic review study of the face mask and related literature.



Appendix 3. Additional results

FIGURE A3.1

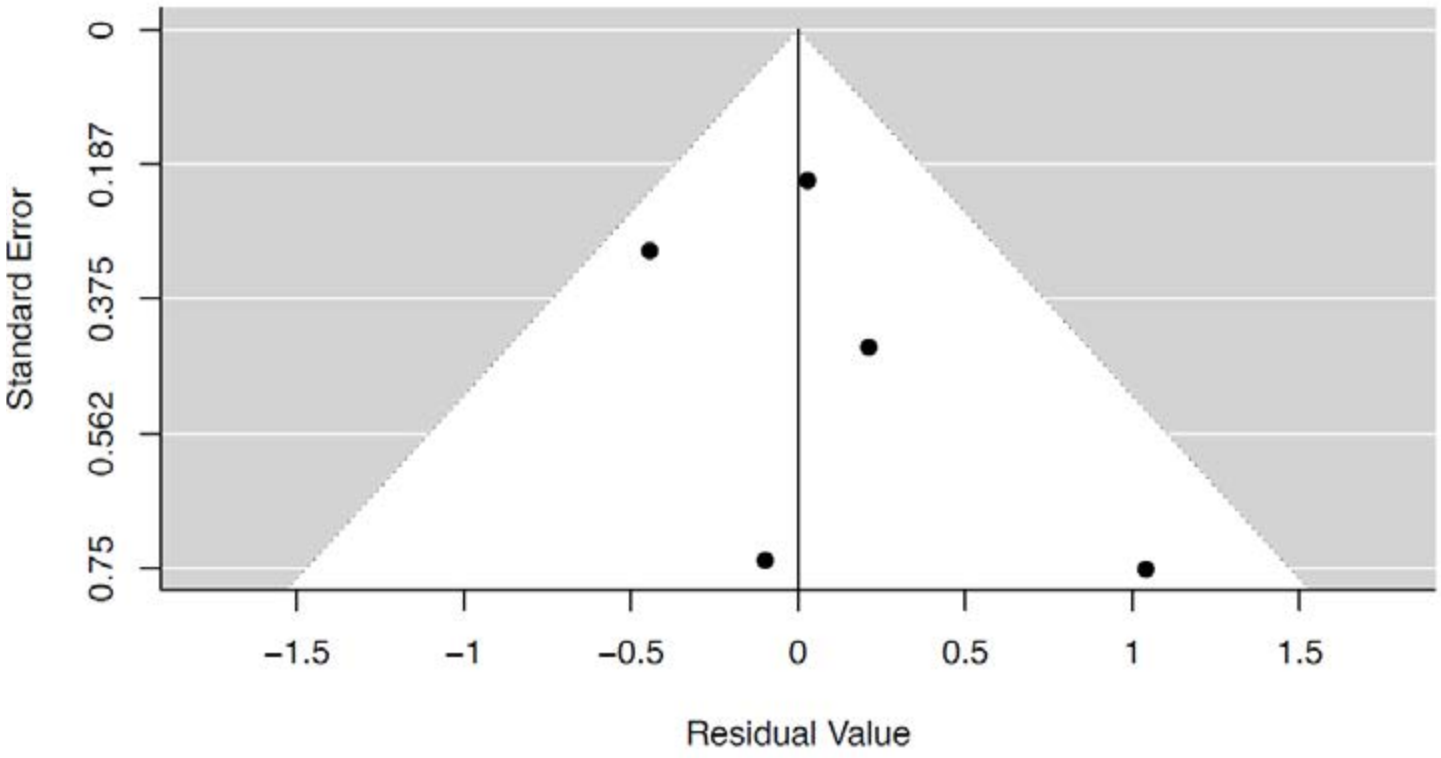
Compliance of various non-pharmaceutical health interventions during previous outbreaks, US studies only.



Note: In these US studies, the majority of the samples are taken from randomly drawn representative national samples of US adults studying SARS (N=1025)[159], response to a hypothetical serious infectious outbreak (N=500)[160], H1N1 (N=1290)[161], national representative US opinion polls 2009-10 (N varies)[162], a random sample of adults in Arizona (H1N1, N=727)[163] and in two counties in North Carolina (H1N1, N=207)[164]. The remainder used convenience samples of adult travellers at 4 international airports (H5N1, N=1301)[165], parents of children in San Antonio, Texas after a H1N1 outbreak (N=727)[166] and an internet survey of Stanford alumni and students (H1N1, N=6249)[167]. A comparative summary of further details about these studies can also be found in[168].

FIGURE A3.2

Funnel plot with pseudo 95% confidence intervals, meta-analysis.



Appendix 4. UK government advice on face coverings (14 June 2020)

Full excerpt from document: HM Government. Working safely during the COVID-19 in construction and other outdoor work. COVID-19 secure guidance for employers, employees and the self-employed, Version 2.0 updated 14 June 2020[147].

There are some circumstances when wearing a face covering may be marginally beneficial as a precautionary measure. The evidence suggests that wearing a face covering does not protect you, but it may protect others if you are infected but have not developed symptoms.

A face covering can be very simple and may be worn in enclosed spaces where social distancing isn't possible. It just needs to cover your mouth and nose. It is not the same as a face mask, such as the surgical masks or respirators used by health and care workers.

Similarly, face coverings are not the same as the PPE used to manage risks like dust and spray in an industrial context. Supplies of PPE, including face masks, must continue to be reserved for those who need them to protect against risks in their workplace, such as health and care workers, and those in industrial settings like those exposed to dust hazards.

It is important to know that the evidence of the benefit of using a face covering to protect others is weak and the effect is likely to be small, therefore face coverings are not a replacement for the other ways of managing risk, including minimising time spent in contact, using fixed teams and partnering for close-up work, and increasing hand and surface washing. These other measures remain the best ways of managing risk in the workplace and government would therefore not expect to see employers relying on face coverings as risk management for the purpose of their health and safety assessments.

Wearing a face covering is optional and not required by law, including in the workplace. If you choose to wear one, it is important to use face coverings properly and wash your hands before putting them on and before taking them off.

Employers should support their workers in using face coverings safely if they choose to wear one. This means telling workers:

- Wash your hands thoroughly with soap and water for 20 seconds or use hand sanitiser before putting a face covering on, and before and after removing it.
- When wearing a face covering, avoid touching your face or face covering, as you could contaminate them with germs from your hands.
- Change your face covering if it becomes damp or if you've touched it.
- Continue to wash your hands regularly.
- Change and wash your face covering daily.
- If the material is washable, wash in line with manufacturer's instructions. If it's not washable, dispose of it carefully in your usual waste.
- Practise social distancing wherever possible.

You can make face-coverings at home and can find guidance on how to do this and use them safely on **GOV.UK**

Appendix 5. GRADE Recommendations

The authors apply GRADE (Grading of Recommendations, Assessment, Development, and Evaluation) recommendations[148]. The advantage of using GRADE is that it ensures both a systematic process and transparency of research and transparently note the quality of evidence for each topic studied. The limitations of GRADE is that the steps and recommendations are narrowly gauged towards medical research. For instance, the first step is an a-priori ranking of 'high' quality to the yardstick of randomized control trials and 'low' to observational studies, with the underlying assumption that RCTs are less prone to bias. Bias is related to lack of blinding, the trial being cut short, etc., which does not cover common bias issues in socio-behavioural research.

Although we find this approach useful for transparency, and explicitly noting the strengths, limitations and our assessment of the quality of evidence, strictly applying GRADE recommendations is problematic for the current study for two reasons. First, our report covers a vast array of social and behavioural research vital to our understanding of face mask and covering wearing, which is by definition almost always observational studies, many of which are considered of very high quality within those disciplines. Second, a core criticism of the face mask literature, and in particular cloth or non-surgical face coverings has been the lack of RCTs. As mentioned in the report and eloquently argued elsewhere[149], this is unrealistic for ethical but also practical reasons. This may be another reason that 'weak' or 'lack of evidence' has been ascribed to face mask and coverings for the general public.

We note there have also been no clinical trials of hand-washing, coughing into your elbow, social distancing and quarantine, yet these measures have been widely adopted and are considered as effective.

TABLE A5.1

GRADE recommendations

Topic	Section	Type of research	Strengths	Limitations	Level quality of evidence
Effectiveness of cloth face coverings.	2.2-2.6	Meta-analysis of infection reduction of cotton masks.	More systematic and empirical examination beyond only a narrative review. Relatively homogeneous studies in similar setting, country.	No RCTs were able to be included, with estimates come from observational research designs only. Studies all in a healthcare setting in one country. Examined SARS and H1N1 and not COVID-19 setting. Small number of studies.	Moderate-quality (to translate to public setting). No broader community settings (e.g., transport, shops) conducted as it is virtually impossible to conduct RCTs
	2.7	Effectiveness of cloth masks by fabric type, construction.	Rigorous study carried out with multiple types of fabrics and hybrid construction. Attention to use by adding measure of 'gap' as proxy for incorrect fit or usage.	Tests carried out in lab and not community setting. May be other measures beyond fit and gap related to effectiveness.	Moderate- to high-quality (need to translate to community setting; replication).
International face mask policy comparative data.	3	International comparative data is scarce with few comparative measures available. Data is taken from Masks4all[170]	Contains data for 188 countries. Direct links to the source of each policy are provided.	Does not divide into different regions (e.g., UK, Scotland, Wales or States in US). Not an official or supranational data source. Lack of other comparative databases to check validity.	Moderate-quality (at least 1 primary source with traceable links).

Topic	Section	Type of research	Strengths	Limitations	Level quality of evidence
Behavioural literature systematic review (high quality unless section otherwise noted below)	4	Highly heterogeneous literature taken from multiple sources of PUBMED, Web of Science, Scopus and preprints (PsyRArix, SocRxiv, SSRN, MedRxiv, bioRxiv) Highly heterogeneous literature with multiple study designs	Captures wide breadth of interdisciplinary research Captures hard to measure topics such as risk perception and public attitudes Preprints capture most recent knowledge on the topic Strength of breadth of knowledge	Disciplines approach topics in varied manners, making direct comparisons sometimes challenging Due to slower publication process of social sciences, COVID-19 studies often pre-prints without peer review (when this is the case it is indicated in the review) Difficult to empirically or systematically analyse as in for example a meta-analysis or RCT	High-quality (contains multiple systematic reviews with consistent results, but we note that in some cases the quality of studies are mixed)
		Beyond COVID-19 and coronavirus, included also literature on previous pandemics such as SARS, H1N1, MERS	Larger body of literature to draw conclusions from Ability to pick up 'lessons learned' that are not possible since COVID-19 is still ongoing in many countries	Differences in pandemics (country, virus) Knowledge not always directly applicable due to national, medical or societal differences (e.g., culture of mask wearing, trust in government)	As above
	4.4	Topic of socio-political systems and trust in government and science	Builds on larger body of research, theories COVID-19 research available using large-scale data and multiple types of research designs	COVID-19 research based on several pre-print non-peer-reviewed studies (indicated in section)	Moderate-quality (smaller base of COVID specific literature from pre-prints)
	4.5	Vulnerable groups & discrimination in relation to COVID-19	Builds on existing literature of discrimination of groups during other pandemics	Most COVID-19 research on this topic are pre-prints and not peer reviewed Experiments of discrimination, small n, selective samples, may not translate to real-world settings	Low-quality to no evidence (COVID-specific research)

Topic	Section	Type of research	Strengths	Limitations	Level quality of evidence
	4.6	Perceived barriers	Extensive material and studies, particularly on COVID-19 since 2020 Fit and comfort examined in detail (virtually all in relation to health care professionals)	Mostly in relation to public health workers, less on general public Fit and comfortable of surgical & respirator masks very different from cloth coverings	High-quality for health workers Limited evidence for general public
Public adherence to face mask coverings and relationship to other interventions	5.1	Cross national comparisons of face mask wearing and coverage during COVID-19	Two nationally representative surveys from different sources of 8 countries (N=66,266) and 15 countries (N=29,000)	Both cover period of mid-March to mid-April 2020 using self-reports Countries at different stages of disease trajectories with varying & changing policies over that period Limited country coverage	Moderate- to high-quality with consistent results across studies
	5.2	Policy packages of non-pharmaceutical interventions	Multiple studies and systematic review across US and multiple pandemics Cross-national COVID-19 study of current interventions	Difficult to separate different interventions, often introduced in tandem Difficult to know whether intervention was mandatory or recommended, plus changes over time	High-quality, multiple studies with consistent results
	5.3	Face mask usage in relation to physical distancing	Meta-analyses that include multiple interventions in health-care settings COVID-19 information on this topic available from governmental websites and news sources	Difficult to translate research from health-care settings to general public Fast moving government advice Information from news sources is not peer-reviewed research	No to low-quality for general public (note: difficult to obtain evidence due to difficulties in separating the impacts of different policies, current topic)

Appendix 6. Preparation of Report

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References

1 DELVE. 2020 Face masks for the general public. See https://rs-delve.github.io/reports/2020/05/04/face-masks-for-the-general-public.html (accessed 26 June 2020).

2 Centres for Disease Control and Prevention (CDC). 2020 Considerations for wearing cloth face coverings. See https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/cloth-face-cover-guidance.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fcoronavirus%2F2019-ncov%2Fprevent-getting-sick%2Fcloth-face-cover.html (accessed 26 June 2020).

3 World Health Organisation (WHO). Advice on the use of masks in the context of COVID-19: interim guidance, 5 June 2020. See https://apps.who.int/iris/handle/10665/332293 (accessed 26 June 2020).

4 Greenhalgh T *et al.* 2020 Face masks for the public during the COVID-19 crisis. BMJ. (doi:10.1136/bmj.m1435).

5 Chu DK *et al.* 2020 Physical distancing, face masks and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis. The Lancet, 395, P1973-1987. (doi:10.1016/S0140-6736(20)31142-9).

6 *Op. cit*, note 5

7 Bartoszko JJ *et al.* 2020 Medical masks vs N95 respirators for preventing COVID-19 in healthcare workers: A systematic review and meta-analysis of randomized trials. Influenza and Other Respiratory Viruses, 14, 365-373. (doi:10.1111/irv.12745).

8 Xiao J *et al*. 2020 Nonpharmaceutical Measures for Pandemic Influenza in Nonhealthcare Settings—Personal Protective and Environmental Measures. Emerg. Infect. Dis. 26, 967–975.

9 Brainard JS, Jones N, Lake I, Hooper L, Hunter P. 2020 Facemasks and similar barriers to prevent respiratory illness such as COVID-19: A rapid systematic review. medRxiv. (doi:10.1101/2020.04.01.20049528).

10 *Op. cit*, note 4

11 Xiao J *et al*. 2020 Nonpharmaceutical Measures for Pandemic Influenza in Nonhealthcare Settings—Personal Protective and Environmental Measures. Emerg. Infect. Dis. 26, 967–975.

12 Brainard JS, Jones N, Lake I, Hooper L, Hunter P. 2020 Facemasks and similar barriers to prevent respiratory illness such as COVID-19: A rapid systematic review. medRxiv. (doi:10.1101/2020.04.01.20049528).

13 Wang Y *et al.* 2020 Reduction of secondary transmission of SARS-CoV-2 in households by face mask use, disinfection and social distancing: a cohort study in Beijing, China. BMJ Global Health, 5, e002794. See https://gh.bmj.com/content/5/5/e002794 (accessed 26 June 2020).

14 Lau JTF *et al.* 2004 SARS transmission, risk factors, and prevention in Hong Kong. Emerging Infectious Diseases, 10, 587–592. (doi:10.3201/eid1004.030628).

15 Wu J *et al.* 2004 Risk factors for SARS among persons without known contact with SARS Patients, Beijing, China. Emerging Infectious Diseases, 10, 210–216. (doi:10.3201/eid1002.030730).

16 Tuan PA *et al.* 2007 SARS transmission in Vietnam outside of the health-care setting. Epidemiology and Infection, 135, 392–401. (doi:10.1017/S0950268806006996).

17 Chu DK *et al*. 2020 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. (doi:10.1016/S0140-6736(20)31142-9).

18 Xiao J *et al*. 2020 Nonpharmaceutical Measures for Pandemic Influenza in Nonhealthcare Settings—Personal Protective and Environmental Measures. Emerg. Infect. Dis. 26, 967–975.

19 *Op. cit*, note 2

20 MacIntyre C R *et al.* 2015 A cluster randomised trial of cloth masks compared with medical masks in healthcare workers. BMJ Open. 5, e006577. (doi:10.1136/bmjopen-2014-006577).

21 Yin W *et al.* 2004. Effectiveness of personal protective measures in prevention of nosocomial transmission of severe acute respiratory syndrome. Zhonghua Liu Xing Bing Xue Za Zhi. 1, 18-22. See https://pubmed.ncbi.nlm.nih.gov/15061941/ (accessed 26 June 2020).

22 Andersen B M. 2019 Prevention and Control of Infections in Hospitals: Practice and Theory. Springer International Publishing. (doi:10.1007/978-3-319-99921-0).

23 *Op. cit* note 5

24 #MASKS4ALL, 2020 What Countries Require Masks in Public or Recommend Masks? See https://masks4all.co/what-countries-require-masks-in-public/ (accessed 26 June 2020).

25 World Health Organisation (WHO). Advice on the use of masks in the context of COVID-19: interim guidance, 6 April 2020. See https://apps.who.int/iris/bitstream/handle/10665/331693/WHO-2019-nCov-IPC_Masks-2020.3-eng.pdf?sequence=1&isAllowed=y (accessed 26 June 2020).

26 European Centre for Disease Prevention and Control (ECDC). Using face masks in the community: reducing COVID-19 transmission from potentially asymptomatic or pre-symptomatic people through the use of face masks. Technical Report 8 April 2020. See https://www.ecdc.europa.eu/sites/default/files/documents/COVID-19-use-face-masks-community.pdf (accessed 26 June 2020).

27 Rothe C *et al.* 2020 Transmission of 2019-nCoV Infection from an Asymptomatic Contact in Germany. NEJM, 382, 970–971. (doi:10.1056/NEJMc2001468).

28 *Op. cit* note 2

29 *Op. cit* note 3

30 Scottish Government. Face coverings mandatory on public transport from 22 June. See https://www.gov.scot/news/face-coverings-mandatory-on-public-transport-from-22-june/ (accessed 26 June 2020).

31 Welsh Government. Face coverings: frequently asked questions. See https://gov.wales/face-coverings-frequently-asked-questions (accessed 26 June 2020).

32 Department for Transport. Face coverings to become mandatory on public transport. See https://www.gov.uk/government/news/face-coverings-to-become-mandatory-on-public-transport (accessed 26 June 2020).

33 Rothstein MA *et al.* 2003 Quarantine and Isolation: Lessons learned from SARS. A Report to the Centers for Disease Control and Prevention. See https://biotech.law.lsu.edu/blaw/cdc/SARS_REPORT.pdf (accessed 26 June 2020).

34 Garcia LP. 2020 Use of facemasks to limit COVID-19 transmission. Uso de máscara facial para limitar a transmissão da COVID-19. Epidemiol Serv Saude. 29, e2020023. (doi:10.5123/S1679-49742020000200021).

35 Ministry of Health Mexico. 2009 Actions to contain transmission of influenza A H1N1. Acciones para contener la transmisión de Influenza A HINI. en Secretaría de Salud, México. See http://www.issste-cmn20n.gob.mx/Archivos%20PDF/Acciones_Basicas_influenza_SS_20090511.pdf (accessed 26 June 2020).

36 Liberati A *et al.* 2009 The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. BMJ. 339, b2700–b2700. (doi:10.1136/bmj.b2700).

37 Stroup DF *et al.* 2000 Meta-analysis of Observational Studies in Epidemiology: A Proposal for Reporting. JAMA, 83, 2008-12. (doi: 10.1001/jama.283.15.2008).

38 Mills MC, Rahal C. 2019 A scientometric review of genome-wide association studies. Communications Biology, 2. (doi:10.1038/s42003-018-0261-x).

39 Mills MC, Rahal C. 2020 The GWAS Diversity Monitor tracks diversity by disease in real time. Nature Genetics, 52, 242–243. (doi:10.1038/s41588-020-0580-y).

40 Van Bavel JJ *et al.* 2020 Using social and behavioural science to support COVID-19 pandemic response. Nature Human Behaviour, 4, 460–471. (doi:10.1038/s41562-020-0884-z).

41 Guyatt GH *et al.* 2008 GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. BMJ. 336, 924–926. (doi:10.1136/bmj.39489.470347.AD).

42 Teasdale E *et al.* 2014 Public perceptions of non-pharmaceutical interventions for reducing transmission of respiratory infection: systematic review and synthesis of qualitative studies. BMC Public Health, 14. See https://bmcpublichealth.biomedcentral.com/articles/10.1186/1471-2458-14-589 (accessed 26 June 2020).

43 Gershon RR *et al.* 2018 Adherence to Emergency Public Health Measures for Bioevents: Review of US Studies. Disaster Med. Public Health Prep. 12, 528–535. (doi:10.1017/dmp.2017.96).

44 *Op. cit* note 42.

45 *Op. cit* note 26

46 Bricker D. 2020 More people say they're wearing masks to protect themselves from COVID-19 since March. IPSOS. See https://www.ipsos.com/en/more-people-say-theyre-wearing-masks-protect-themselves-covid-19-march (accessed 26 June 2020).

47 Caress AL *et al.* 2010 Exploring the needs, concerns and behaviours of people with existing respiratory conditions in relation to the H1N1 'swine influenza' pandemic: a multicentre survey and qualitative study. Health Technology Assessment, 14, 1-108. (doi:10.3310/hta14340-01).

48 Teasdale E, Yardley L. 2011 Understanding responses to government health recommendations: public perceptions of government advice for managing the H1N1 (swine flu) influenza pandemic. Patient Education and Counselling, 85, 413–418. (doi:10.1016/j.pec.2010.12.026).

49 Gray L *et al.* 2012 Community responses to communication campaigns for influenza A (H1N1): a focus group study. BMC Public Health. 12, 205. (doi:10.1186/1471-2458-12-205).

50 Menni C *et al.* 2020 Real-time tracking of self-reported symptoms to predict potential COVID-19. Nature Medicine. (doi:10.1038/s41591-020-0916-2).

51 Teasdale E *et al.* 2012 The importance of coping appraisal in behavioural responses to pandemic flu. British Journal of Health Psychology, 17, 44–59. (doi:10.1111/j.2044-8287.2011.02017.x).

52 Bish A, Michie S. 2010 Demographic and attitudinal determinants of protective behaviours during a pandemic: A review. British Journal of Health Psychology, 15, 797–824. (doi:10.1348/135910710X485826).

53 Cowling BJ *et al.* 2010 Face masks to prevent transmission of influenza virus: a systematic review. Epidemiology and Infection, 138, 449–456. (doi:10.1017/S0950268809991658).

54 Goodwin, R *et al.* 2009 Initial psychological responses to Influenza A, H1N1 ("Swine flu"). BMC Infectious Diseases, 9. (doi:10.1186/1471-2334-9-166).

55 Lau JTF *et al.* 2011 Changes in knowledge, perceptions, preventive behaviours and psychological responses in the pre-community outbreak phase of the H1N1 epidemic. Epidemiology and Infection, 139, 80–90. (doi:10.1017/S0950268810001925).

56 Lau JTF *et al.* 2007 Anticipated and current preventive behaviours in response to an anticipated human-to-human H5N1 epidemic in the Hong Kong Chinese general population. BMC Infectious Diseases, 7. (doi:10.1186/1471-2334-7-18).

57 Liao Q *et al.* 2010 Fielding, Situational Awareness and Health Protective Responses to Pandemic Influenza A (H1N1) in Hong Kong: A Cross-Sectional Study. PLoS One, 5, e13350. (doi:10.1371/journal.pone.0013350).

58 Prati G *et al.* 2011 Compliance with recommendations for pandemic influenza H1N1 2009: the role of trust and personal beliefs. Health Education Research, 26, 761–769. (doi:10.1093/her/cyr035).

59 Rubin GJ *et al.* 2010 The impact of communications about swine flu (influenza A H1N1v) on public responses to the outbreak: results from 36 national telephone surveys in the UK. Health Technology Assessment, 14, 183-266. (doi:10.3310/hta14340-03).

60 Rubin GJ *et al.* 2009 Public perceptions, anxiety, and behaviour change in relation to the swine flu outbreak: cross sectional telephone survey. BMJ, 339, b2651–b2651. (doi:10.1136/bmj.b2651).

61 Floyd DL *et al.* 2000 A Meta-Analysis of Research on Protection Motivation Theory. Journal of Applied Psychology, 30, 407–429. (doi:10.1111/j.1559-1816.2000.tb02323.x).

62 *Op. cit* note 61

63 *Op. cit* note 41

64 Cava MA *et al.* 2005 Risk Perception and Compliance with Quarantine During the SARS Outbreak. Journal of Nursing Scholarship, 37, 343–347. (doi:10.1111/j.1547-5069.2005.00059.x).

65 Wise T *et al.* 2020 Changes in risk perception and protective behaviour during the first week of the COVID-19 pandemic in the United States. PsyArXiv Preprints. (doi:10.31234/osf.io/dz428).

66 Perrotta D *et al.* 2020 Behaviours and attitudes in response to the COVID-19 pandemic: insights from a cross-national Facebook survey. medRxiv. (doi:10.1101/2020.05.09.20096388).

67 *Op. cit* note 42

68 *Op. cit* note 49

69 Hilton S, Smith E. 2010 Public views of the UK media and government reaction to the 2009 swine flu pandemic. BMC Public Health, 10. (doi:10.1186/1471-2458-10-697).

70 Seale H *et al.* 2012 Examining the knowledge, attitudes and practices of domestic and international university students towards seasonal and pandemic influenza. BMC Public Health, 12. (doi:10.1186/1471-2458-12-307).

71 *Op. cit* note 70

72 Joffe H. 2003 Risk: From perception to social representation. British Journal of Social Psychology, 42, 55–73. (doi:10.1348/0144666037632 76126).

73 *Op. cit* note 46

74 *Op. cit* note 32

75 *Op. cit* note 32

76 *Op. cit* note 32

77 *Op. cit* note 32

78 Chow A *et al.* 2020 Unintended consequence: influenza plunges with public health response to COVID-19 in Singapore. The Journal of Infection, S0163-4453, 30262-0. (doi:10.1016/j.jinf.2020.04.035).

79 *Op. cit*, note 46

80 Betsch C *et al.* 2017 On the benefits of explaining herd immunity in vaccine advocacy. Nature Human Behaviour, 1. (doi:10.1038/s41562-017-0056).

81 Gelfand MJ *et al.* 2011 Differences between tight and loose cultures: a 33-nation study. Science, 332, 1100–1104. (doi:10.1126/science.1197754).

82 Painter M, Qiu T. 2020 Political beliefs affect compliance with COVID-19 social distancing orders. SSRN Preprint. (doi:10.2139/ssrn.3569098).

83 *Op. cit* note 67

84 Rothgerber H *et al.* 2020 Politicizing the COVID-19 pandemic: ideological differences in adherence to social distancing. PsyArXiv Preprint. (doi:10.31234/osf.io/k23cv).

85 Bakshy E *et al.* 2015 Exposure to ideologically diverse news and opinion on Facebook. Science, 348, 1130–1132. (doi:10.1126/science.aaa1160).

86 Battiston P *et al.* 2020 Trust in science and experts during the COVID-19 outbreak in Italy. OSF Preprints. (doi:10.31219/osf.io/twuhj).

87 Smith SS. 2020 Race and trust. Annual Review of Sociology, 36, 453-475. (doi:10.1146/annurev.soc.012809.102526).

88 Boulware, LE. 2003 Race and trust in the health care system. Public Health Reports, 118, 358-365. (doi:10.1016/S0033-3549(04)50262-5).

89 Dowd JB *et al.* 2020 Demographic science aids in understanding the spread and fatality rates of COVID-19. PNAS, 117, 9696–9698. (doi:10.1073/pnas.2004911117).

90 Nepomuceno MR *et al.* 2020 Besides population age structure, health and other demographic factors can contribute to understanding the COVID-19 burden. PNAS, 117, 13881–13883. (doi:10.1073/pnas.2008760117).

91 Richardson S *et al.* 2020 Presenting characteristics, comorbidities, and outcomes among 5700 patients hospitalized with COVID-19 in the New York City area. JAMA. 323, 2052-2059. (doi:10.1001/jama.2020.6775).

92 Verhagen, DM *et al.* 2020 Forecasting spatial, socioeconomic and demographic variation in COVID-19 health care demand in England and Wales. BMC Medicine, 18. (doi:10.1186/s12916-020-01646-2).

93 *Op. cit* note 64

94 *Op. cit* note 67

95 Goldstein E, Lipsitch M. 2020 Temporal rise in the proportion of both younger adults and older adolescents among COVID-19 cases in Germany: evidence of lesser adherence to social distancing practices? medRxiv. (doi:10.1101/2020.04.08.20058719).

96 *Op. cit* note 67

97 Peckham H *et al.* 2020 Sex-Bias in COVID-19: A Meta-Analysis and Review of Sex Differences in Disease and Immunity. SSRN Preprint. (doi:10.21203/rs.3.rs-23651/v1).

98 Carbon CC. 2020 The Psychology of Wearing Face Masks in Times of the COVID-19 Pandemic. SSRN PrePrint. (doi:10.2139/ssrn.3584834).

99 Cohn SK. 2012 Pandemics: waves of disease, waves of hate from the Plague of Athens to A.I.D.S.*. Historical Research, 85, 535–555. (doi:10.1111/j.1468-2281.2012.00603.x).

100 Russell A. 2020 The rise of coronavirus hate crimes. The New Yorker. See https://www.newyorker.com/news/letter-from-the-uk/the-rise-of-coronavirus-hate-crimes (accessed 26 June 2020).

101 Xio Z *et al.* 2020 The face mask and the embodiment of stigma. PsyArXiv Preprint. (doi:10.31234/osf.io/fp7z8).

102 Siu JYM. 2010 Another nightmare after SARS: knowledge perceptions of and overcoming strategies for H1N1 influenza among chronic renal disease patients in Hong Kong. Qualitative Health Research, 20, 893–904 (doi:10.1177/1049732310367501).

103 Ferng Y *et al.* 2011 Barriers to mask wearing for influenza-like illnesses among urban hispanic households. Public Health Nursing, 28, 13–23. (doi:10.1111/j.1525-1446.2010.00918.x).

104 Wu H *et al.* 2020 Facemask shortage and the novel coronavirus disease (COVID-19) outbreak: Reflections on public health measures. EClinicalMedicine. 21, 100329. (doi:10.1016/j.eclinm.2020.100329).

105 Yuan EJ *et al.* 2020 Where to buy face masks? Survey of applications using Taiwan's open data in the time of coronavirus disease 2019. Journal of the Chinese Medical Association, 83, 557-560. (doi:10.1097/JCMA.0000000000000325).

106 Wang MW *et al.* 2020 Mask crisis during the COVID-19 outbreak. European Review for Medical and Pharmacological Sciences, 24, 3387–3399. (doi:10.26355/eurrev_202003_20707).

107 *Op. cit* note 32

108 *Op. cit* note 32

109 *Op. cit* note 32

110 *Op. cit* note 46

111 Witte K, Allen M. 2000 A meta-analysis of fear appeals: implications for effective public health campaigns. Health, Education and Behaviour, 27, 591–615. (doi:10.1177/109019810002700506).

112 Presidenxa de Consigilio die Ministri. Ordinaza n. 11/2020 Il commissario straodrdinario per l'attuazione e il coordinamento delle misure di contenimento e contrasto dell'emergenza epidemiologica COVID-19. See http://www.governo.it/sites/new.governo.it/files/CSCovid19_Ord_11-2020-txt.pdf (accessed 26 June 2020).

113 Adams-Prassl A *et al.* 2020 Inequality in the impact of the coronavirus shock: new survey evidence for the UK. Cambridge Working Papers in Economics. (doi:10.17863/CAM.52477).

114 Baum NM *et al.* 2009 "Listen to the People": Public deliberation about social distancing measures in a pandemic. The American Journal of Bioethics, 9, 4–14. (doi:10.1080/15265160903197531).

115 *Op. cit* note 48

116 *Op. cit* note 64

117 Luo P *et al.* 2020 Topical rh-aFGF: An effective therapeutic agent for facemask wearing-induced pressure sores. Dermatologic Therapy. (doi:10.1111/dth.13745).

118 *Op. cit* note 105

119 *Op. cit* note 67

120 *Op. cit* note 46

121 *Op. cit* note 2

122 Goldberg M *et al.* 2020 Mask-wearing increased after a government recommendation: a natural experiment in the U.S. during the COVID-19 pandemic. PsyArXiv Preprint. (doi:10.31234/osf.io/uc8nz).

123 *Op. cit* note 67

124 *Op. cit* note 42

125 *Op. cit* note 5

126 *Op. cit* note 1

127 UK Prime Minister's Office. PM announces easing of lockdown restrictions: 23 June 2020. See https://www.gov.uk/government/news/pm-announces-easing-of-lockdown-restrictions-23-june-2020 (accessed 26 June2020).

128 Block P *et al.* 2020 Social network-based distancing strategies to flatten the COVID-19 curve in a post-lockdown world. Nature Human Behaviour, 4, 588–596. (doi:10.1038/s41562-020-0898-6).

129 *Op. cit* note 64

130 *Op. cit* note 47

131 *Op. cit* note 70

132 Prieto Rodgriguez MA *et al.* 2012 La visión de la ciudadanía sobre la epidemia de gripe H1N1 2009-2010: Un enfoque cualitativo. Index de Enfermería. 21, 38–42. (doi:10.4321/S1132-12962012000100009).

133 *Op. cit* note 42

134 *Op. cit* note 43

135 *Op. cit* note 24

136 *Op. cit* note 3

137 *Op. cit* note 40

138 HM Government. Working safely during the COVID-19 in construction and other outdoor work. COVID-19 secure guidance for employers, employees and the self-employed, Version 2.0 updated 14 June 2020. See https://assets.publishing.service.gov.uk/media/5eb961bfe90e070834b6675f/working-safely-during-covid-19-construction-outdoors-140620.pdf (accessed 26 June 2020).

139 Alwan NA *et al.* 2020 Evidence informing the UK's COVID-19 public health response must be transparent. The Lancet, 395, 1036-1037. (doi:10.1016/S0140-6736(20)30667-X).

140 *Op. cit* note 4

141 Greenhalg T. 2020 Will COVID-19 be evidence-based medicine's nemesis? PLoS Med. 17. (doi:10.1371/journal.pmed.1003266).

142 *Op. cit* note 143

143 Brainard JS, Jones N, Lake I, Hooper L, Hunter P. 2020 Facemasks and similar barriers to prevent respiratory illness such as COVID-19: A rapid systematic review. medRxiv. (doi:10.1101/2020.04.01.20049528).

144 Miyazawa D, Kaneko G. 2020 Face mask wearing rate predicts country's COVID-19 death rates. medRxiv. (doi:10.1101/2020.06.22.20137745).

145 *Op. cit* note 41

146 Xiao J *et al*. 2020 Nonpharmaceutical Measures for Pandemic Influenza in Nonhealthcare Settings—Personal Protective and Environmental Measures. Emerg. Infect. Dis. 26, 967–975.Brainard JS, Jones N, Lake I, Hooper L, Hunter P. 2020 Facemasks and similar barriers to prevent respiratory illness such as COVID-19: A rapid systematic review. medRxiv. (doi:10.1101/2020.04.01.20049528).

147 https://assets.publishing.service.gov.uk/media/5eb961bfe90e070834b6675f/working-safely-during-covid-19-construction-outdoors-140620.pdf (accessed June 23 2020)(95) Section 6.1, p. 25

148 *Op. cit* note 41

149 *Op. cit* note 4

150 Zhang D *et al.* 2013 Factors Associated with Household Transmission of Pandemic (H1N1) 2009 among Self-Quarantined Patients in Beijing, China. PLoS One. 8, e77873. (doi:10.1371/journal.pone.0077873).

151 Liu W *et al.* 2009 Risk factors for SARS infection among hospital healthcare workers in Beijing: a case control study. Tropical Medicine and International Health, 14, 52–59. (doi:10.1111/j.1365-3156.2009.02255.x).

152 Seto W *et al.* 2003 Effectiveness of precautions against droplets and contact in prevention of nosocomial transmission of severe acute respiratory syndrome (SARS). Lancet. 361, 1519–1520. (doi: 10.1016/s0140-6736(03)13168-6).

153 *Op. cit* note 15

154 Konda A *et al.* 2020 Aerosol Filtration Efficiency of Common Fabrics Used in Respiratory Cloth Masks. ACS Nano. 14, 6339–6347. (doi:10.1021/acsnano.0c03252).

155 *Op. cit* note 23

156 *Op. cit* note 67

157 Soper GA, 1919 The lessons of the pandemic. Science 49, 501-506. (doi:10.1126/science.49.1274.501).

158 *Op. cit* note 23

159 Blendon RJ *et al.* 2004 The public's response to severe acute respiratory syndrome in Toronto and the United States. Clinical Infectious Diseases, 38, 925–931 (doi:10.1086/382355).

160 Blendon RJ *et al.* 2006 Attitudes toward the use of quarantine in a public health emergency in four countries. Health Affairs, 25, W15–W25. (doi:10.1377/hlthaff.25.w15).

161 Ibuka Y *et al.* 2010 The dynamics of risk perceptions and precautionary behaviour in response to 2009 (H1N1) pandemic influenza. BMC Infectious Diseases, 10, 296. (doi:10.1186/1471-2334-10-296).

162 SteelFisher, GK *et al.* 2010 The public's response to the 2009 H1N1 influenza pandemic. NEJM, 362, e65. (doi:10.1056/NEJMp1005102).

163 Kim Y *et al.* 2015 Public risk perceptions and preventive behaviours during the 2009 H1N1 influenza pandemic. Disaster Medicine and Public Health Preparedness, 9, 145–154. (doi:10.1017/dmp.2014.87).

164 Horney JA *et al.* 2010 Intent to receive pandemic influenza A (H1N1) vaccine, compliance with social distancing and sources of information in NC, 2009. PLoS One. 5, e11226. (doi:10.1371/journal.pone.0011226).

165 Yanni EA *et al.* 2010 Knowledge, attitudes, and practices of US travelers to Asia regarding seasonal influenza and H5N1 avian influenza prevention measures. Journal of Travel Medicine, 17, 374–381. (doi:10.1111/j.1708-8305.2010.00458.x).

166 Loustalot F *et al.* 2011 Household transmission of 2009 pandemic influenza A (H1N1) and nonpharmaceutical interventions among households of high school students in San Antonio, Texas. Clinical Infectious Diseases, 52, S146–S153. (doi:10.1093/cid/ciq057).

167 Jones JH, Salathé M. 2009 Early assessment of anxiety and behavioural response to novel swine-origin influenza A(H1N1). PLoS One, 4, e8032. (doi:10.1371/journal.pone.0008032).

168 *Op. cit* note 43

169 *Op. cit* note 23

170 *Op. cit* note 23

171 *Op. cit* note 23

DISCLAIMER

This paper has drawn on the most recent evidence as of 26 June 2020 and has not been subject to formal peer-review. Further evidence on this topic is constantly published and the Royal Society and British Academy may return to this topic in the future. This independent overview of the science has been provided in good faith by experts and the Royal Society and British Academy and paper authors who accept no legal liability for decisions made based on this evidence.

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