Community use of facemasks and similar barriers to prevent respiratory illness such as COVID-19: A rapid scoping review

Background: Evidence for facemask wearing in the community to protect against respiratory disease is unclear.

Aim: To assess efficacy of wearing facemasks in the community to prevent respiratory disease, and recommend improvements to this evidence base.

Methods: We systematically searched Scopus, Embase and MEDLINE for studies evaluating incidence of respiratory disease after facemask wearing (or not). Narrative synthesis and random-effects meta-analysis of attack rates for primary and secondary prevention were performed, subgrouped by design, setting, type of face barrier, and who wore the facemask. Preferred outcome was influenza-like illness. GRADE quality assessment was undertaken and evidence base deficits described.

Results: 33 studies (12 RCTs) were included. Mask-wearing reduced primary infection by between 6% (in RCTs, OR 0.94, 95%CI 0.75-1.19) and 61% (cohort studies OR 0.85, 95%CI 0.32 to 2.27; case control studies OR 0.39, 95%CI 0.18-0.84; cross-sectional studies OR 0.61, 95%CI 0.45-0.85). RCTs suggested lowest secondary attack rates when both well and ill house-hold members wore masks (OR 0.81, 95%CI 0.48 - 1.37). While poor compliance and controls wearing masks probably underestimated effects in RCTs, effects are likely overestimated in observational studies where mask wearing is associated with other risk-averse behaviours. GRADE was low or very low quality.

Conclusion: Wearing facemasks may reduce risk of primary respiratory infection, probably by 6-15%. This review raises significant issues about balancing evidence from RCTs and observational studies when these give very different conclusions and both observational studies and RCTs are at risk of significant bias. Studies specifically addressing COVID-19 infection are required.

Keywords: Coronavirus, facemask, influenza-like-illness, Hajj, respiratory infection

INTRODUCTION

On 30 January 2020 the World Health Organisation (WHO) declared a Public Health Emergency of International Concern (PHEIC) in response to the emergence of a novel coronavirus in Wuhan, China [1]. On the 11th March 2020 the WHO declared the COVID-19 epidemic to be a pandemic [2]. By the end of June 2020 nearly 500,000 global deaths had been linked to COVID-19 [3]. It is not clear when this outbreak will abate.

Amongst other advice widely sought by the public in response to this outbreak, was whether wearing face coverings, especially medical-grade coverings (e.g. masks, goggles or similar) might reduce the risk of catching or transmitting disease [4], particularly in domestic and public places. Sales of inexpensive facemask products soared following the PHEIC declaration, leading to potential shortages for health care workers [5-10]. Previous systematic reviews on the efficacy of using facemasks in community settings assessed facemasks combined with other personal protection measures [11-13] or mixed health care workers with non-health care workers [12, 14-16]. Those that specifically examined community use had focused only on RCTs [17, 18]. Overall, the reviews had mixed conclusions about community settings: that facemasks were highly effective [12, 16], definitely effective [14, 19], may be effective for protection [17, 18, 20] or did not have a statistically significant effect [12]. There has been near consensus that the evidence base is inadequate [11, 14, 17-20].

We responded to this information demand by undertaking a rapid systematic review to evaluate evidence that might indicate the effectiveness of wearing facemasks in the community in relation to the transmission of respiratory disease. This review therefore considers the quality of the evidence for these outcomes and produces recommendations on how to improve this evidence base.

METHODS

Review aims

We aimed to assess the effectiveness of wearing a face barrier (mask, goggles, shield, veil) in community settings to prevent transmission of respiratory illness, such as from coronaviruses, rhinoviruses, influenza viruses or tuberculosis, and recommend how to improve this evidence base. We use the words mask and facemask interchangeably as umbrella terms for diverse facial coverings that may cover any combination of mouth, nose and/or eyes.

Search Strategy

Two recent literature reviews [12, 18] were consulted to find eleven exemplar studies [21-31] that met our eligibility criteria. We designed search strategies that were sensitive enough to find these exemplar studies and similar research, yet specific enough exclude most irrelevant records. The bibliographic databases Scopus, Embase and Medline were searched with the phrases in Box 1. We read other systematic reviews [11, 12, 14, 16-20] on similar non-pharmaceutical practices to look for any missing primary studies.

Assessment of inclusion

Two authors (JB, NJ or IL) independently screened the retrieved titles and abstracts. Disagreements were resolved by discussion with other authors. The inclusion criteria were:

- Original research (not a review, guidelines, discussion, regulations, debate or commentary) published in English since January 1980
- The research needed to describe facemask use that might prevent disease transmission or symptom development among people in the community (rather than prevent transmission to or from professionals in clinical settings)
- The study described an observed relationship between facemask use and respiratory symptoms or infection by respiratory pathogens: (e.g. influenza, coronavirus, tuberculosis).
- There was a comparator or control group (non-barrier users) for whom disease incidence data were also collected
- Any study design in any country, as long as comparator data were available

The full text of each article that passed screening was retrieved and eligibility verified as part of data extraction.

BOX 1 Bibliographic database search phrases

SCOPUS

TITLE-ABS-KEY (
(facemask? OR "facemasks?" OR mask? OR goggle? OR faceshield? OR respirator OR respirators)
AND
(influenza OR flu OR sars OR tuberculosis or mers OR coronav* OR "cov" OR respiratory-syndrome OR wuhan or "ncov")
)
AND
(LIMIT-TO (SUBJAREA , "MEDI") OR LIMIT-TO (SUBJAREA , "NURS") OR LIMIT-TO (SUBJAREA , "IMMU"))

EMBASE & Medline via OVID

[(facemask* or "face-mask*" or mask* or goggle* or face-shield* or respirator or respirators).kw,ti,ab.]
and
[(influenza or flu or sars or tuberculosis or mers or coronav* or "cov" or respiratory-syndrome or "ncov" or wuhan).kw,ti,ab.]

Data Extraction for efficacy

Characteristics of included studies, qualitative data and numbers of participants who developed respiratory outcomes in relevant study arms were extracted. The preferred specific outcome was influenza-like illness (ILI), defined by WHO as fever ≥ 38 C° with cough and onset ≤ 10 days previous [32]. Where a WHO-definition was unavailable, we accepted other similar case definitions (e.g. cold symptoms, acute respiratory infections, clinical cases of influenza or SARS) so that we could expand the evidence base and because of the often reported 'atypical' presentations and disease courses of COVID-19 [33]. Where studies reported three arms we extracted data for arms where the only difference was whether a facemask was worn (e.g. hand hygiene and no masks vs. hand hygiene + facemasks).

Synthesis of evidence on effectiveness

Characteristics of included studies were tabulated. Numbers of infections and numbers of people at risk in each study arm were input to Review Manager 5.3 [34] for meta-analysis by JB, verified by other authors. We calculated pooled odds ratios using Mantel-Haenszel random effects meta-analysis (due to expected high heterogeneity) separately for primary prevention (when no cases were yet been identified) and prevention of secondary cases (when an individual was diagnosed with an infection and the aim was to prevent contacts from getting disease). We subgrouped by study design (RCT, cohort, case control or cross-sectional), and presented these subgroups in forest plots without global pooling to understand consistency of evidence across study designs. We also showed the trend of evidence within settings (subgrouping by setting). For secondary transmission (in RCTs)

we subgrouped by who wore the facemask: index case, well contacts of the index case, or both. Outcomes after wearing faceveils were also presented where evidence was available.

Quality of evidence

Risk of bias of included RCTs was assessed (by LH) using the Cochrane risk of bias tool [35], and biases and limitations identified by primary study authors of observational studies were noted. We assessed the quality of evidence using the GRADE framework, based on the RCT data and supported or contradicted by observational data [35]. To further evaluate the translational value of the evidence, we report narratively on other aspects of the studies. Compliance or contamination in RCTs was noted, along with any information about what kinds of masks controls wore as part of the contamination. Formal quality assessment checklists were not undertaken for observational studies, but we noted the kinds of masks worn (if reported). For all primary studies, settings and outcomes were recorded and are discussed with respect to their relevance to aspects of COVID-19 outbreak control. For all primary studies, we noted limitations as reported by the original investigators and discuss narratively any general limitations these imply for the wider evidence base.

RESULTS

Study selection and overview

Figure 1 shows the study selection process. Study characteristics are shown in Table 1. GRADE assessments are shown in Table 2. The search was updated through 19 June 2020. Altogether, 1233 titles and abstracts were retrieved from Scopus, and 1657 from Embase with Medline. Our search located all 11 exemplar articles. Combining and deduplicating left 2081 articles. Of these 236 were not written in English and 81 were published before 1980, so were removed. This left 1764 titles and abstracts to screen, of which 47 were selected to be collected in full text. Full text review identified 26 eligible studies. Checking other systematic reviews on protective effects of facemask use in the community identified a further seven studies (five in the Hajj setting and two in other community settings). The specific mask types were mostly unspecified, but where specified they were surgical medical grade items (n=14). Of the 33 included studies, 12 were designed as cluster-RCTs, five were cohort studies, six were case control and 10 were cross-sectional. Data suitable for meta-analysis were reported in 31 studies. Settings included schools, university residences, visits to health care providers, family households, the Hajj mass gathering, and non-specific community places. Most studies reported on influenza-like illness (ILI) as an outcome (n=14) or respiratory illness (n=10). Fever with respiratory symptoms, upper respiratory tract infection, lab-confirmed or clinical

influenza, toxic pneumonitis, common colds, other respiratory symptoms, evidence of immunity to SARS-CoV from serology and positive rt-PCR results for SARS-CoV-2 were also used as dichotomous outcomes when ILI was unavailable. All mass gathering studies were associated with the Hajj pilgrimage. Table S1 lists additional characteristics of the included studies.

Table 1. Setting, study design and outcome for each included study.

Study	Setting	Design	Outcome	Comparison
Aiello 2010 pilot [21]	University residences	cluster RCT	'fever' symptoms	Allocated arms
Aiello 2012 [22]	University residences	cluster RCT	ILI symptoms	Allocated arms
Alfelali 2019 as RCT [36]	Hajj pilgrimage	cluster RCT	respiratory illness	Allocated arms
Alfelali 2019 [36]	Hajj pilgrimage	as cohort	respiratory illness	Used facemask daily or not
Al-Jasser 2012 [37]	Hajj pilgrimage	cross sectional	respiratory illness	Most of the time vs. sometimes/never
Balaban 2012 [38]	Hajj pilgrimage	retrospective cohort	respiratory illness	Had facemask practice or not
Barasheed 2014 [39]	Hajj pilgrimage, pilgrims sleeping near index cases	cluster RCT	respiratory illness	Allocated arms
Canini 2010 [23]	Household with index case wearing mask who had been symptomatic < 48 hrs	cluster RCT	ILI	Allocated arms
Choudhry 2006 men [40]	Hajj pilgrimage (males)	prospective cohort	respiratory illness	Most of time vs. sometimes/never
Choudhry 2006 women [40]	Hajj pilgrimage (female)	prospective cohort	respiratory illness	Most of the time vs. sometimes/never
Cowling 2008 [25]	Household, wearing masks soon after index case flu test	cluster RCT	ILI	Allocated arms
Cowling 2009 [24]	Household, wearing masks soon after index case flu test	cluster RCT	ILI	Both arms also had hand hygiene intvn
Deris 2010 [41]	Hajj pilgrimage	cross-sectional	ILI	Allocated arms
Emamian 2013 [42]	Hajj pilgrimage	nested case control	respiratory illness (not colds)	Wore a mask or not
Fan 2020 [43]	Chinese citizens (82% students) living in Iran and subsequently evacuated	cohort	confirmed SARS-CoV-2	Wore a mask or not before left Iran
Hashim 2016 [44]	Hajj pilgrimage	cross-sectional	respiratory illness	Used or not; multiple types of face cover used
Jolie 1998 [45]	Pig farm, visiting students	cross-sectional	respiratory symptoms	During visit or not
Kim 2012 [46]	Schools	cross-sectional	Lab-confirmed influenza	Continuous or irregular vs. non-users
Larson 2010 [26]	Care settings	cluster RCT	ILI	Allocated arms
Lau 2004a [28]	Public places, visitors	case control	ILI = suspected SARS	Frequently vs. seldom/no
Lau 2004b [27]	Hospital, visitors to SARS index cases	case control	ILI = suspected SARS	During visit or not

MacIntyre 2009 [29]	Household, adults wear mask caring for sick child	cluster RCT	ILI	Allocated arms
MacIntyre 2016 [47]	Household, index case wearing mask when symptomatic <24 hrs	cluster RCT	ILI	Allocated arms
Shin 2018 control [48]	Community	cohort	common cold symptoms	Habitually wearing a facemask or not
Shin 2018 intvn arm [48]	Community	cohort	common cold symptoms	Habitually wearing a facemask or not
Simmerman 2011 [30]	Household	cluster RCT	ILI	Allocated arms
Suess 2012 [31]	Household, members wearing masks when index case symptomatic <48 hrs	cluster RCT	ILI	Allocated arms
Tahir 2019 [49]	Poultry farm, workers	cross-sectional	serological tests for A(H9N2) influenza	Always vs. sometimes/never
Tuan 2007 [50]	Households with lab-confirmed SARS case	cohort	SARS-CoV-1 positive serology	Sometimes/mostly vs. never
Uchida 2017 [51]	Schools	cross-sectional	influenza	Mask wearing ever vs. never
Wu 2004 [52]	Community	case control	SARS (WHO case definition)	Always vs. sometimes/never
Wu 2016 [53]	Hospital, visitors without contact with known case	cross-sectional	ILI	Habitually or not
Zein 2002 [54]	Hajj pilgrimage, masks supplied for all	cross-sectional	URTI symptoms	Used masks or not
Zhang 2013a [55]	Long-haul flights	case control	ILI linked to H1N1 (WHO case definition)	Wore mask for entire flight or not
Zhang 2013b [56]	Households, self-quarantine with index patient	case control	lab-confirmed influenza (H1N1)	Daily mask wearing or not

Abbreviations: ILI = influenza-like illness, intvn = intervention, RCT= randomised controlled trial, URTI=upper respiratory tract infection, WHO = World Health Organisation.

Table 2. Summary of GRADE findings

Masks compared to no masks for influenza-like illness

Patient or population: people without ILI, either in contact with a person with ILI (secondary transmission) or not (primary prevention). **Setting**: Any. **Intervention (or exposure)**: Advice to wear a mask and/or provision of masks (or wearing a mask). **Comparison**: No advice to wear a mask/advice to not wear masks (or not wearing a mask).

Setting (outcome always ILI)	Study type	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	№ of participants (studies)	Quality of the evidence (GRADE)	Comments
		Risk without masks	Risk with masks				
Primary prevention, well wear masks	RCTs	108 per 1,000	**102 per 1,000** (83 to 125)	**OR 0.94** (0.75 to 1.19)	5183 (3 RCTs)	⨁⨁◯◯ LOW [a,b,c,d,e]	Wearing a mask may very slightly reduce the odds of primary infection with influenza-like illness (ILI) by around 6 to 15%. Low-quality evidence (downgraded once each for risk of bias and imprecision).
	Cohort studies	197 per 1,000	**141 per 1,000**	**OR 0.85** (0.32 to 2.27)	5217 (7 cohorts)		
	Case control studies	405 per 1,000	**184 per 1,000**	**OR 0.39** (0.18 to 0.84)	1501 (4 studies)		
	Cross-sectional	341 per 1,000	**223 per 1,000**	**OR 0.61** (0.45 to 0.85)	10,058 (8 studies)		
Secondary transmission, use of masks in homes, only ill person wears mask	RCTs	68 per 1,000	**65 per 1,000** (38 to 108)	**OR 0.95** (0.53 to 1.72)	903 (2 RCTs)	⨁◯◯◯ VERY LOW [f,g]	When one household member becomes ill with an ILI the effect of their wearing a mask on the odds of house-mates developing ILI is unclear, as the evidence is of very low quality (downgraded once for risk of bias, twice for imprecision).
	Case control studies	248 per 1,000	**491 per 1,000**	**OR 2.93** (1.48 to 5.81)	162 (1 study)		
Secondary transmission, use of masks in homes, only	RCTs	121 per 1,000	**114 per 1,000** (86 to 150)	**OR 0.93** (0.68 to 1.28)	2078 (2 RCTs)	⨁⨁◯◯ LOW [f,h]	House-mates wearing masks once another household member has contracted ILI may modestly reduce the odds of further household members

Table 2. Summary of GRADE findings

Masks compared to no masks for influenza-like illness

Patient or population: people without ILI, either in contact with a person with ILI (secondary transmission) or not (primary prevention). **Setting**: Any. **Intervention (or exposure)**: Advice to wear a mask and/or provision of masks (or wearing a mask). **Comparison**: No advice to wear a mask/advice to not wear masks (or not wearing a mask).

Setting (outcome always ILI)	Study type	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	№ of participants (studies)	Quality of the evidence (GRADE)	Comments
		Risk without masks	**Risk with masks**				
well person(s) wears mask	Cohort studies	45 per 1,000	**53 per 1,000**	**OR 1.04** (0.05 to 19.52)	163 (1 study)		becoming ill by around 7%. Low quality evidence (downgraded twice overall for risk of bias, imprecision and inconsistency).
	Case control studies	337 per 1,000	**329 per 1,000**	**OR 0.96** (0.50 to 1.86)	162 (1 study)		
Secondary transmission, use of masks in homes, both well and ill person(s) wear mask	RCT	192 per 1,000	**173 per 1,000** (121 to 242)	**OR 0.81** (0.48 to 1.37)	1605 (5 RCTs)	⨁⨁◯◯ LOW [h,i,j]	Both house-mates and the infected household member wearing masks once one household member has contracted ILI may modestly reduce the odds of further household members becoming ill by around 19%. Low quality evidence (downgraded twice overall for risk of bias, imprecision and inconsistency).
	Case control studies	173 per 1,000	**86 per 1,000**	**OR 0.45** (0.18 to 1.05)	191 (1 study)		

***The risk in the intervention group** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI). **CI:** Confidence interval; **OR:** Odds ratio

Table 2. Summary of GRADE findings

Masks compared to no masks for influenza-like illness

Patient or population: people without ILI, either in contact with a person with ILI (secondary transmission) or not (primary prevention). **Setting**: Any. **Intervention (or exposure)**: Advice to wear a mask and/or provision of masks (or wearing a mask). **Comparison**: No advice to wear a mask/advice to not wear masks (or not wearing a mask).

Setting (outcome always ILI)	Study type	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	№ of participants (studies)	Quality of the evidence (GRADE)	Comments
		Risk without masks	Risk with masks				

GRADE Working Group grades of evidence
High quality: We are very confident that the true effect lies close to that of the estimate of the effect
Moderate quality: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low quality: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect
Very low quality: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

Explanations

a. Risk of bias: Outcome assessors were not blinded for ILI (as outcomes are self-reported and participants could not be blinded), but were for lab-based diagnoses (not shown). Allocation concealment often unclear. Downgraded once.
b. Inconsistency: I2 was 19%. Evidence from other study designs were roughly confirmatory of a small beneficial effect. Not downgraded.
c. Indirectness: measured exactly what we wanted to know re primary prevention. Not downgraded.
d. Imprecision: the 95% CIs included both benefits and harms. Downgraded once.
e. Publication bias: no suggestion of publication bias, not downgraded.
f. Risk of bias: In most trials outcome assessors were not blinded (as outcomes are self-reported and participants could not be blinded), and allocation concealment was often unclear. Downgraded once.
g. Imprecision: the 95% CIs included both big benefits and big harms. Downgraded twice.
h. Imprecision: the 95% CIs included both benefits and harms. Downgraded once.
i. Risk of bias: In most trials outcome assessors were not blinded (as outcomes were self-reported and participants could not be blinded). Downgraded once in conjunction with inconsistency.
j. Inconsistency: I2 was 53%. Downgraded in conjunction with Risk of Bias (downgraded once between both factors).

Prevention of primary infection, subgrouping by study design

Figure 2 shows grouping of results by study design. Pooled data are presented to calculate a single odds ratio to compare and contrast study designs. Risk of biases for RCTs are also presented.
The three RCTs which measured the prevention of primary infection, indicated a slight, non-significant, reduction in the odds of primary infection with ILI (OR 0.94, 95%CI 0.60-1.07). Heterogeneity was low (I^2 29%).

Evidence from the five cohort comparisons suggested facemasks provided some primary protection (OR 0.85, 95%CI 0.32-2.27), although these findings were not significant. Heterogeneity was very high (I^2 = 96%) and the men-only cohort from Choudhry et al. [40] was a noticeable outlier. This set of studies included observational data based on actual facemask wearing habits from one study originally designed as an RCT [36].

Among four case control (OR 0.39, 95%CI 0.18-0.84, I^2 77%) and eight cross-sectional studies (OR 0.61, 95%CI 0.45-0.85, I^2 95%), pooled data suggested that facemask wearing was protective, but effects were highly heterogeneous. Of the cross-sectional studies, Tahir et al. [49] and Zein [54] were noticeable outliers. Removal of these outliers still indicates facemask wearing as protective, although no longer significant, and heterogeneity falls slightly (OR 0.89, 95%CI 0.78-1.01, I^2 = 64%, data not shown).

Two studies on primary prevention did not provide suitable data for pooling. Gautret *et al*. 2011 [57] gave no data but reported that they had done analysis supporting their conclusions to comment narratively that facemasks were protective against respiratory tract infections. Another study without reported original data, Hashim *et al.* 2016 [44], concluded that respirators were not effective protection against ILI.

GRADE assessment suggested that wearing a mask may slightly reduce the odds of primary infection with influenza-like illness (ILI) by around 6 to 15%. (i.e. somewhere between the effects seen in RCTs and the effects seen in cohort studies; likely to be the most robust of the observational studies). This was low-quality evidence (downgraded once each for risk of bias and imprecision).

Prevention of primary infection by exposure setting

Figure 3 groups results by exposure setting. Pooling of data from different study designs is not appropriate to calculate a single odds ratio statistic. Most results favoured facemask wearing.

Facemask wearing was mostly protective (the midpoint-estimates of most included studies favoured facemask wearing) in the general community (3 cohort and 2 case control of which 2 studies were significantly protective), university residences (2 cluster-randomised RCTs, neither significant at p = 0.05) and in schools (2 cross-sectional studies, neither significantly protective).

One case control study for visits to health care clinics without a known index patient suggested that mask-wearing was significantly protective against primary infection. One case control study on air travel suggested a protective but non-significant relationship between mask-wearing and avoiding infection.

The results were less consistent (the point-estimates showed both protective and non-protective relationships) for animal contact (2 cross-sectional studies, 1 significant protective finding) and suggested masks were mostly not significant in getting or avoiding disease when used at mass gatherings (all Hajj pilgrims; 1 cluster-randomised RCT, 2 cohort, 1 case control and 3 cross-sectional; 2 significant protective findings.

Prevention of primary infection among face veil wearers

Figure 4 shows data from two studies (cross-sectional and cohort) examining case incidence among women who wore face veils often/always while on Hajj pilgrimage. Both studies indicate a protective but non-significant relationship.

Secondary transmission

Figure 5 shows results for secondary transmission subdivided by study design and who wore the facemask (index patient, well contacts or both). Presented are pooled data to calculate a single odds ratio and risk of biases for each study design. Findings from the two RCTs when only infected persons wore a facemask, suggested a very small, non-significant protective effect (OR 0.95, 95%CI 0.53 to 1.72, I^2 0%). The GRADE assessment suggested that the effect of the infected person wearing a facemask was unclear due to very low quality evidence (downgraded once for risk of bias, twice for imprecision).

The protective effect was very small if only the well people wore facemasks (OR 0.93, 95% CI 0.68 to 1.28, I^2 11%, 2 RCTs). The GRADE assessment combining data from the two RCTs, and single cohort and case-control studies suggested low quality evidence. House-mates wearing masks once another household member has contracted ILI may modestly reduce the odds of further household members becoming ill by around 7%. Low quality evidence (downgraded twice overall for risk of bias, imprecision and inconsistency).

Pooled data from five RCTs where both infected and non-infected household members wore facemasks showed the odds of infection fell modestly and not significantly (OR 0.81, 95%CI 0.48 to 1.37, I^2 45%).

Findings from the one case control study [27] where both infected and non-infected household members wore facemasks indicated a large risk reduction but this was not significant at $p < 0.05$ (OR 0.45, 95%CI 0.18 to 1.10). Zhang et al 2013b. [56] is a case control study that separated results for facemask wearing by whether masks were worn by either index patient or contacts. These results significantly favoured no mask wearing by index patients (OR 2.93, 95%CI 1.48 to 5.81) and found negligible attack rate differences between case and control households when contacts wore masks (OR 0.96, 95%CI 0.5 to 1.86). The final comparison in Figure 5 draws data from a single cohort study [50] where 95% of contacts never wore masks during contact with confirmed SARS-CoV-1 cases. No significant effect from mask-wearing (or not) was found (OR 1.04, 95%CI 0.05-19.52).

GRADE assessment for these 5 RCTs and one case-control study suggested that both house-mates and the infected household member wearing masks once one household member has contracted ILI may modestly reduce the odds of further household members becoming ill by around 19%. This was low quality evidence (downgraded twice overall for risk of bias, imprecision and inconsistency).

Secondary transmission and early commencement of facemask wearing

Figure 6 shows results for the four secondary transmission RCT studies providing data for attack rates when facemask wearing started < 36 hours after index patient became symptomatic. A single odds ratio statistic and risk of biases for RCTs are presented. Facemask wearing was not protective in this subgroup analysis (OR 1.36, 0.66-2.79, I^2 0%). Some of the original investigators in these studies undertook logistic regression to adjust their findings for other confounders and found

evidence that early facemask wearing (< 36 hours after symptom onset) could be protective, but acknowledged that their models were underpowered.

Quality of Evidence

Many of the included RCTs reported that participants did not follow instructions about wearing facemasks [19, 24, 25, 29, 36, 47]. Several reported that some controls wore facemasks during the monitoring period [25, 30, 47], while many intervention participants did not wear facemasks the majority of the time [24-26, 29, 47]. All of the RCTs included in our review provided specific facemasks (usually surgical grade, rarely P2 or equivalent grade respirator) with instructions on how to wear the facemask, how often they should be changed and how to hygienically dispose of used facemasks. No information was reported about the types of facemasks that (contrary to protocol) some controls in RCTs used. Very few of the observational studies collected information about what type of face covering was used. Several studies highlight potential problems of recall bias [27, 49, 53]. Other studies note that potential confounding factors were not explored [38, 43, 56].

Apart from studies conducted during the Hajj, the evidence base for primary transmission in specific settings such as public transport, schools, cafeterias and shops was minimal (Figure 3). The only mass-gathering setting where facemask wearing evidence has been gathered and published is the Hajj.

DISCUSSION

The quality of the evidence is problematic. We believe that RCT evidence under-estimated efficacy while observational studies have over-estimated how protective facemask wearing can be because of un-measured co-factors that cause confounding. For example, those who choose to wear masks may be more risk averse in general so undertake many protective activities alongside wearing a mask. Therefore, specific accurate estimates of the degree of protectiveness of facemasks from the currently available evidence base are unreliable. Our best estimate is that the effect of wearing a facemask is between the effects seen in RCTs and the effects seen in cohort studies, or around 6 to 15% reduction in disease transmission.

Lack of evidence on transmission in specific settings is also problematic, given that effectiveness is likely to differ between settings, and infection control measures will need to vary by setting. The

evidence is arguably insufficient to comment meaningfully on primary transmission reduction in any setting other than the Hajj. It is not ideal that the only mass gathering event studied is the Hajj which is exceptional for high contact rates over 10-20 days and which attracts a narrow demographic (older and relatively wealthy individuals) [41, 44, 54, 57, 58]. These features are unlike many other mass gatherings.

Producing clear evidence from observational and randomised studies that facemasks are effective (or not) in slowing COVID-19 spread would be desirable. Only one of the studies included in this review were about people exposed to potential SARS-CoV-2 infection [43]. There has sometimes been resistance to wearing face coverings, recommended or mandated to try to slow spread of COVID-19 [59, 60]. These tense conflicts seem likely to undermine all public health measures intended to slow the spread of COVID-19. This situation underscores the need to produce reliable and clear primary research.

Population level studies that consider COVID-19 spread before and after mask-wearing policies (and combinations of other control measures) were introduced in various localities [61-65] have more often than not concluded that mask-wearing mandates or recommendations seemed to accelerate epidemic decline in early 2020. Analyses of impacts of non-pharmaceutical interventions (NPI) in the COVID-19 pandemic are preliminary and some have been criticised for indirect measurements, use of selective data and inappropriate analytical methods [66-68]. Compliance information is also not usually included in these natural experiment studies. It is not clear why population studies have tended to show definitive findings on mask-wearing which are not reflected in primary research. Aligning findings from the different evidence bases, and establishing a secure consensus about which NPI measures are effective, would be desirable and also might illuminate less recognised transmission pathways and best opportunities for risk reduction.

While RCTs may underestimate effects of facemasks, because of compliance problems in both intervention and control groups, compliance with mask wearing seems very likely to be partial in real life, too. This problem reflects a wider issue around public health interventions. Archie Cochrane himself pointed out “the gulf, which has been much under-estimated, between the scientific measurements based on RCTs and the benefit measurement in the community” [69]. There are in fact two questions here. The first is do facemasks, if used appropriately, reduce the risk of transmission from an infected individual and/or protect an uninfected person if in the presence of someone with COVID-19. The second question is whether public health interventions that require or

encourage people to wear face coverings actually achieve their objective of reducing diseases in the wider population. It is this later question that is the most important and the answer remains unclear.

Limitations

Due to the rapidity of this review we did not consider other article archives or databases such as Google Scholar, CINAHL and medRXiv. Our search terms were designed to be more specific than they were sensitive. We addressed all types of respiratory symptoms and diagnoses; in reality, transmission pathways even among respiratory viruses do vary somewhat individually. A good reason to generate a larger evidence base is to make it possible to meaningfully separate pathogens and outcomes. "Mask" had to be among title/abstract/key words, and we are aware that "mask" was more likely to be among the title/abstract/key words if mask-wearing was linked to significant effects. In practice, the search strategy meant that our search terms were slightly biased into finding articles where masks had been protective rather than having no effect. We also considered only dichotomous outcomes; we did not classify outcomes by severity of symptoms or other clinical outcomes [70]. It is possible that facemask wearing reduced duration or severity of symptoms experienced due to reducing infectious dose received, although not actual disease.

We did not undertake cost-benefit analysis. The sudden emergence of COVID-19 led to high community demand for face barriers and raised valid concerns that insufficient supplies of facemasks were available for health care workers [9, 10]. The environmental and economic costs of regularly using facemasks are notable, and only partly abated by reuse. Other efforts have been made to calculate the balance of all benefits and costs in facemask wearing for disease prevention [71-74].

We make no comment on the relative utility of other proposed protective measures compared to facemask wearing, such as self-isolation or frequent handwashing: we have not undertaken research on those measures for comparison. We did not formally assess likelihood of publication bias in the primary research evidence base.

CONCLUSIONS

Original primary research is needed on whether and to what extent facemasks reduce transmission of COVID-19 and other respiratory communicable diseases. Future RCT investigations should

explore methods to enhance compliance in both intervention and control participants and ensure these are reported. All studies should also report information about the types of facemasks people wore (in both control and intervention arms), frequency of wear and the range of other protective measures used. It would be helpful to understand how masks were used by research participants, if masks were washed, disinfected or how they were disposed of, as well as duration of wear. Future observational studies should carefully collect information on and adjust for key confounders. Research needs to be sensitive to settings and types of contact as well as the specific disease. The impact of when mask wearing starts and type of prevention (eg., primary, early or later secondary prevention) needs investigating further, and is likely to differ between diseases. This is especially true if studies can be well powered to produce more definitive results, or if evidence should emerge about facemask use within homes before symptom onset or within a very short period (perhaps 4-12 hours) after symptom onset.

SUPPLEMENTAL See Table S1 for extra characteristics of included studies.

FIGURE CAPTIONS and NOTES

Figure 1. Study selection process
Figure 2. Mask wearing to prevent primary infection, by study design
Figure 3. Mask wearing to prevent primary infection, by exposure setting
Figure 4. Faceveil wearing to prevent primary infection
Figure 5. Mask wearing to prevent secondary infection, transmission mostly within households
Figure 6. Mask wearing to prevent secondary infection starting < 36 hours after onset in index patient, transmission within households

Notes for all Figures:
Notes: CI: confidence interval; df: degrees of freedom; ILI: influenza-like illness; intvn: intervention; M-H: Mantel-Haenszel, RCT: randomized controlled trial. See Table 1 for study setting, study design, outcome, comparison (when not allocated arms in RCTs) and any concurrent other intervention in both study arms.

REFERENCES

1. World Health Organization. Statement on the second meeting of the International Health Regulations (2005) Emergency Committee regarding the outbreak of novel coronavirus (2019-nCoV): WHO; 2020 [updated 30 Jan. Available from: https://www.who.int/news-room/detail/30-01-2020-statement-on-the-second-meeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-outbreak-of-novel-coronavirus-(2019-ncov).
2. World Health Organization. WHO Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020: WHO; 2020 [Available from: https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020
3. John Hopkins University Coronavirus Resource Centre. Coronavirus COVID-19 Global Cases by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU): JHU; 2020 [Available from: https://coronavirus.jhu.edu/map.html.
4. Gajanan M. Can Face Masks Prevent Coronavirus? Experts Say That Depends. Time. 2020 31 Jan.
5. Asgari N, Wells P. Face mask shortage hits Europe and US as coronavirus spreads. Financial Times. 2020 30 Jan.
6. Carter SL. Sold-Out Coronavirus N95 Face Masks Offer a Lesson in Price Gouging. Bloombergcom. 2020 31 Jan.
7. O'Connor K. Coronavirus: face masks sell out but are unlikely to stop germs. The Times. 2020 1 Feb.
8. Taylor K. Costco is selling out of surgical masks in South Korea, as the country battles the spread of the coronavirus. Business Insider. 2020 3 Feb.
9. Wu H, Huang J, Zhang CJ, He Z, Ming W-k. Facemask shortage and the novel coronavirus (2019-nCoV) outbreak: Reflection on public health measures. 2020.
10. Seriously people - STOP BUYING MASKS! [press release]. Twitter, 29 Feb 2020.
11. Saunders-Hastings P, Crispo JAG, Sikora L, Krewski D. Effectiveness of personal protective measures in reducing pandemic influenza transmission: A systematic review and meta-analysis. Epidemics. 2017;20:1-20.
12. Jefferson T, Foxlee R, Del Mar C, Dooley L, Ferroni E, Hewak B, et al. Physical interventions to interrupt or reduce the spread of respiratory viruses: Systematic review. BMJ. 2008;336(7635):77-80.
13. Wong VWY, Cowling BJ, Aiello AE. Hand hygiene and risk of influenza virus infections in the community: A systematic review and meta-analysis. Epidemiology and Infection. 2014;142(5):922-32.
14. bin-Reza F, Lopez Chavarrias V, Nicoll A, Chamberland ME. The use of masks and respirators to prevent transmission of influenza: A systematic review of the scientific evidence. Influenza and other Respiratory Viruses. 2012;6(4):257-67.
15. Wang M, Barasheed O, Rashid H, Booy R, El Bashir H, Haworth E, et al. A cluster-randomised controlled trial to test the efficacy of facemasks in preventing respiratory viral infection among Hajj pilgrims. Journal of Epidemiology and Global Health. 2015;5(2):181-9.
16. Chu DK, Akl EA, Duda S, Solo K, Yaacoub S, Schünemann HJ, et al. Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis. The Lancet. 2020.
17. Cowling BJ, Zhou Y, Ip DKM, Leung GM, Aiello AE. Face masks to prevent transmission of influenza virus: a systematic review. Epidemiology and Infection. 2010;138(4):449-56.
18. MacIntyre CR, Chughtai AA. Facemasks for the prevention of infection in healthcare and community settings. BMJ (Online). 2015;350.

19. Barasheed O, Alfelali M, Mushta S, Bokhary H, Alshehri J, Attar AA, et al. Uptake and effectiveness of facemask against respiratory infections at mass gatherings: A systematic review. International Journal of Infectious Diseases. 2016;47:105-11.
20. Benkouiten S, Brouqui P, Gautret P. Non-pharmaceutical interventions for the prevention of respiratory tract infections during Hajj pilgrimage. Travel Medicine and Infectious Disease. 2014;12(5):429-42.
21. Aiello AE, Murray GF, Perez V, Coulborn RM, Davis BM, Uddin M, et al. Mask use, hand hygiene, and seasonal influenza-like illness among young adults: A randomized intervention trial. Journal of Infectious Diseases. 2010;201(4):491-8.
22. Aiello AE, Perez V, Coulborn RM, Davis BM, Uddin M, Monto AS. Facemasks, hand hygiene, and influenza among young adults: A randomized intervention trial. PLoS ONE. 2012;7(1):e29744.
23. Canini L, Andreoletti L, Ferrari P, Angelo DR, Blanchon T, Lemaitre M, et al. Surgical mask to prevent influenza transmission in households: A cluster randomized trial. PLoS One. 2010;5(1).
24. Cowling BJ, Chan KH, Fang VJ, Cheng CKY, Fung ROP, Wai W, et al. Facemasks and hand hygiene to prevent influenza transmission in households: A cluster randomized trial. Annals of Internal Medicine. 2009;151(7):437-46.
25. Cowling BJ, Fung ROP, Cheng CKY, Fang VJ, Chan KH, Seto WH, et al. Preliminary findings of a randomized trial of non-pharmaceutical interventions to prevent influenza transmission in households. PLoS ONE 2008;3(5):e2101.
26. Larson EL, Ferng YH, Wong-McLoughlin J, Wang S, Haber M, Morse SS. Impact of non-pharmaceutical interventions on URIs and influenza in crowded, urban households. Public Health Reports. 2010;125(2):178-91.
27. Lau JTF, Lau M, Kim JH, Wong E, Tsui HY, Tsang T, et al. Probable Secondary Infections in Households of SARS Patients in Hong Kong: Emerging Infectious Diseases. 10 (2) (pp 235-243), 2004. Date of Publication: February 2004.; 2004.
28. Lau JTF, Tsui H, Lau M, Yang X. SARS Transmission, Risk Factors, and Prevention in Hong Kong: Emerging Infectious Diseases. 10 (4) (pp 587-592), 2004. Date of Publication: April 2004.; 2004.
29. MacIntyre CR, Cauchemez S, Dwyer DE, Seale H, Cheung P, Browne G, et al. Face mask use and control of respiratory virus transmission in households. Emerging Infectious Diseases. 2009;15(2):233-41.
30. Simmerman JM, Suntarattiwong P, Levy J, Jarman RG, Kaewchana S, Gibbons RV, et al. Findings from a household randomized controlled trial of hand washing and face masks to reduce influenza transmission in Bangkok, Thailand. Influenza and other Respiratory Viruses. 2011;5(4):256-67.
31. Suess T, Remschmidt C, Schink SB, Schweiger B, Nitsche A, Schroeder K, et al. The role of facemasks and hand hygiene in the prevention of influenza transmission in households: Results from a cluster randomised trial; Berlin, Germany, 2009-2011. BMC Infectious Diseases. 2012;12.
32. World Health Organization. WHO surveillance case definitions for ILI and SARI 2014 [updated January 2014. Available from: https://www.who.int/influenza/surveillance_monitoring/ili_sari_surveillance_case_definition/en/.
33. Menni C, Valdes AM, Freidin MB, Sudre CH, Nguyen LH, Drew DA, et al. Real-time tracking of self-reported symptoms to predict potential COVID-19. Nature Medicine. 2020:1-4.
34. The Cochrane Collaboration. Review Manager (RevMan). 5.3 ed. Copenhagen: The Nordic Cochrane Centre; 2014.
35. Atkins D, Best D, Briss P, et al. GRADE Working Group. Grading quality of evidence and strength of recommendations. BMJ. 2004;328.
36. Alfelali M, Haworth EA, Barasheed O, Badahdah A-M, Bokhary H, Tashani M, et al. Facemask versus No Facemask in Preventing Viral Respiratory Infections During Hajj: A Cluster Randomised Open Label Trial. SSRN (Lancet preprints). 2019.

37. Al-Jasser FS, Kabbash IA, AlMazroa MA, Memish ZA. Patterns of diseases and preventive measures among domestic hajjis from Central, Saudi Arabia. Saudi Med J. 2012;33(8):879-86.
38. Balaban V, Stauffer WM, Hammad A, Afgarshe M, Abd-Alla M, Ahmed Q, et al. Protective practices and respiratory illness among US travelers to the 2009 Hajj. Journal of Travel Medicine. 2012;19(3):163-8.
39. Barasheed O, Almasri N, Badahdah AM, Heron L, Taylor J, McPhee K, et al. Pilot randomised controlled trial to test effectiveness of facemasks in preventing influenza-like illness transmission among Australian hajj pilgrims in 2011. Infectious Disorders - Drug Targets. 2014;14(2):110-6.
40. Choudhry A, Al Mudaimegh K, Turkistani A, Al Hamdan N. Hajj-associated acute respiratory infection among hajjis from Riyadh. Eastern Mediterranean Health Journal. 2006;12:300-9.
41. Deris ZZ, Hasan H, Sulaiman SA, Wahab MSA, Naing NN, Othman NH. The prevalence of acute respiratory symptoms and role of protective measures among Malaysian Hajj pilgrims. Journal of Travel Medicine. 2010;17(2):82-8.
42. Emamian MH, Hassani AM, Fateh M. Respiratory tract infections and its preventive measures among Hajj pilgrims, 2010: A nested case control study. International Journal of Preventive Medicine. 2013;4(9):1030-5.
43. Fan J, Liu X, Shao G, Qi J, Li Y, Pan W, et al. The epidemiology of reverse transmission of COVID-19 in Gansu Province, China. Travel Medicine and Infectious Disease. 2020:101741.
44. Hashim S, Ayub ZN, Mohamed Z, Hasan H, Harun A, Ismail N, et al. The prevalence and preventive measures of the respiratory illness among malaysian pilgrims in 2013 hajj season. Journal of Travel Medicine. 2016;23(2).
45. Jolie R, Backstrom L, Thomas C. Health problems in veterinary students after visiting a commercial swine farm: Canadian journal of veterinary research = Revue canadienne de recherche veterinaire. 62 (1) (pp 44-48), 1998. Date of Publication: Jan 1998.; 1998.
46. Kim CO, Nam CM, Lee DC, Chang J, Lee JW. Is abdominal obesity associated with the 2009 influenza A (H1N1) pandemic in Korean school-aged children? Influenza and other Respiratory Viruses. 2012;6(5):313-7.
47. MacIntyre CR, Zhang Y, Chughtai AA, Seale H, Zhang D, Chu Y, et al. Cluster randomised controlled trial to examine medical mask use as source control for people with respiratory illness. BMJ Open. 2016;6(12).
48. Shin K, Wakabayashi H, Sugita C, Yoshida H, Sato K, Sonoda T, et al. Effects of orally administered lactoferrin and lactoperoxidase on symptoms of the common cold. International Journal of Health Sciences. 2018;12(5):44-50.
49. Tahir MF, Abbas MA, Ghafoor T, Dil S, Shahid MA, Bullo MMH, et al. Seroprevalence and risk factors of avian influenza H9 virus among poultry professionals in Rawalpindi, Pakistan. Journal of Infection and Public Health. 2019;12(4):482-5.
50. Tuan P, Horby P, Dinh P, Mai L, Zambon M, Shah J, et al. SARS transmission in Vietnam outside of the health-care setting. Epidemiology & Infection. 2007;135(3):392-401.
51. Uchida M, Kaneko M, Hidaka Y, Yamamoto H, Honda T, Takeuchi S, et al. Effectiveness of vaccination and wearing masks on seasonal influenza in Matsumoto City, Japan, in the 2014/2015 season: An observational study among all elementary schoolchildren. Preventive Medicine Reports. 2017;5:86-91.
52. Wu J, Xu F, Zhou W, Feikin DR, Lin CY, He X, et al. Risk Factors for SARS among Persons without Known Contact with SARS Patients, Beijing, China. Emerging Infectious Diseases. 2004;10(2):210-6.
53. Wu S, Ma C, Yang Z, Yang P, Chu Y, Zhang H, et al. Hygiene behaviors associated with influenza-like illness among adults in Beijing, China: A large, population-based survey: PLoS ONE. 11 (2) (no pagination), 2016. Article Number: e0148448. Date of Publication: 01 Feb 2016.; 2016.
54. Zein U, editor The role of using masks to reduce acute upper respiratory tract infections in pilgrims. 4th Asia Pacific travel health conference; 2002 Oct 20; Shanghai, PR China.

55. Zhang L, Peng Z, Ou J, Zeng G, Fontaine RE, Liu M, et al. Protection by face masks against influenza A(H1N1)pdm09 virus on trans-pacific passenger aircraft, 2009. Emerging Infectious Diseases. 2013;19(9):1403-10.
56. Zhang D, Liu W, Yang P, Zhang Y, Li X, Germ KE, et al. Factors associated with household transmission of pandemic (H1N1) 2009 among self-quarantined patients in Beijing, China. PloS one. 2013;8(10).
57. Gautret P, Vu Hai V, Sani S, Doutchi M, Parola P, Brouqui P. Protective measures against acute respiratory symptoms in French pilgrims participating in the Hajj of 2009. Journal of Travel Medicine. 2011;18(1):53-5.
58. Shirah BH, Zafar SH, Alferaidi OA, Sabir AM. Mass gathering medicine (Hajj Pilgrimage in Saudi Arabia): The clinical pattern of pneumonia among pilgrims during Hajj. Journal of Infection and Public Health. 2017;10(3):277-86.
59. Mccollough JB. 'You could literally kill someone': Masks become a new COVID-19 battleground. Los Angeles Times. 2020 May 4.
60. Zhang JG. Food Workers Are Experiencing Hostility and Violence From Customers Refusing to Wear Masks. EATERcom. 2020 May 21.
61. Hunter PR, Colon-Gonzalez F, Brainard JS, Rushton S. Impact of non-pharmaceutical interventions against COVID-19 in Europe: a quasi-experimental study. medRxiv. 2020.
62. Brauner JM, Sharma M, Mindermann S, Stephenson AB, Gavenčiak T, Johnston D, et al. The effectiveness and perceived burden of nonpharmaceutical interventions against COVID-19 transmission: a modelling study with 41 countries. medRxiv. 2020.
63. Zhang R, Li Y, Zhang AL, Wang Y, Molina MJ. Identifying airborne transmission as the dominant route for the spread of COVID-19. Proceedings of the National Academy of Sciences. 2020.
64. Cheng VC, Wong S-C, Chuang VW, So SY, Chen JH, Sridhar S, et al. The role of community-wide wearing of face mask for control of coronavirus disease 2019 (COVID-19) epidemic due to SARS-CoV-2. Journal of Infection. 2020.
65. Lyu W, Wehby GL. Community Use Of Face Masks And COVID-19: Evidence From A Natural Experiment Of State Mandates In The US: Study examines impact on COVID-19 growth rates associated with state government mandates requiring face mask use in public. Health Affairs. 2020:10.1377/hlthaff. 2020.00818.
66. Centre SM. Expert reaction to preprint looking at a possible blueprint out of lockdown based on analysis of effects of various measures used in several European countries: Science Media Centre; 2020 [Available from: https://www.sciencemediacentre.org/expert-reaction-to-preprint-looking-at-a-possible-blueprint-out-of-lockdown-based-on-analysis-of-effects-of-various-measures-used-in-several-european-countries/.
67. Haber N, Larremore DB, Goodman SN, Grabowski MK, Wada N, Lessler J, et al. Formal request for the retraction of Zhang et al. 2020: META-RESEARCH INNOVATION CENTER AT STANFORD; 2020 [updated 18 June 2020.
68. Soltesz K, Gustafsson F, Timpka T, Jaldén J, Jidling C, Heimerson A, et al. Sensitivity analysis of the effects of non-pharmaceutical interventions on COVID-19 in Europe. medRxiv. 2020.
69. Cochrane AL. Archie Cochrane in his own words: Selections arranged from his 1972 introduction to "effectiveness and efficiency: Random reflections on the health services". Controlled Clinical Trials. 1989;10(4):428-33.
70. Paulo AC, Correia-Neves M, Domingos T, Murta AG, Pedrosa J. Influenza infectious dose may explain the high mortality of the second and third wave of 1918–1919 influenza pandemic. PLoS One. 2010;5(7).
71. Baracco G, Eisert S, Eagan A, Radonovich L. Comparative cost of stockpiling various types of respiratory protective devices to protect the health care workforce during an influenza pandemic. Disaster Medicine and Public Health Preparedness. 2015;9(3):313-8.

72. Rivera P, Louther J, Mohr J, Campbell A, DeHovitz J, Sepkowitz KA. Does a cheaper mask save money? The cost of implementing a respiratory personal protective equipment program. Infection Control and Hospital Epidemiology. 1997;18(1):24-7.
73. McGain F, Story D, Lim T, McAlister S. Financial and environmental costs of reusable and single-use anaesthetic equipment. British Journal of Anaesthesia. 2017;118(6):862-9.
74. Coulter J. Air pollution masks symptom of throwaway society. China Daily. 2017 18 Jan.