

Cloth Masks May Prevent Transmission of COVID-19: An Evidence-Based, Risk-Based Approach

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Physical distancing, hand hygiene, and disinfection of surfaces are the cornerstones of infection control during the coronavirus disease 2019 (COVID-19) pandemic. At the same time, governments, international agencies, policymakers, and public health officials have been debating the validity of recommending use of nonmedical masks by the general public to reduce the transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). We believe that these decisions should be informed by evidence. Although no direct evidence indicates that cloth masks are effective in reducing transmission of SARS-CoV-2, the evidence that they reduce contamination of air and surfaces is convincing and should suffice to inform policy decisions on their use in this pandemic pending further research.

Cloth does not stop isolated virions. However, most virus transmission occurs via larger particles in secretions, whether aerosol (<5 μm) or droplets (>5 μm), which are generated directly by speaking, eating, coughing, and sneezing; aerosols are also created when water evaporates from smaller droplets, which become aerosol-sized droplet nuclei. The point is not that some particles can penetrate but that some particles are stopped, particularly in the outward direction. Every virus-laden particle retained in a mask is not available to hang in the air as an aerosol or fall to a surface to be later picked up by touch.

Filtration efficiency is the ability of a material to block transmission; it is expressed as a percentage (Figure) and assessed using surrogate markers, including biological aerosols. Mask standards set by ASTM International require tests with latex spheres and aerosolized *Staphylococcus aureus* (1), but masks are not assessed separately for every pathogen: Filtration efficiency depends on the physical retention of particles of different sizes, regardless of which pathogen the particle contains.

Cloth can block droplets and aerosols, and layers add efficiency. Filtration efficiency for single layers of different types of cotton cloth in a bioaerosol (0.2 μm) experiment was between 43% and 94%, compared with 98% to 99% for fabric from disposable medical masks (2). In a summary of similar observations, single layers of scarfs, sweatshirts, T-shirts, and towels were associated with filtration efficiency of 10% to 40% in experiments using NaCl aerosol (0.075 μm) (3). For tea towel fabric, studied with aerosol-sized particles, filtration efficiency in experiments using a bacterial marker was 83% with 1 layer and 97% with 2 layers, compared with 96% for a medical mask (4). In experiments using virus, 1 layer of tea towel had 72% efficiency and 1 layer of

T-shirt fabric 51%, compared with 90% for a medical mask (4). A 2020 study confirms that some fabrics block clinically useful percentages of transmission, even for aerosols and even in single layers; multiple layers improve efficiency (5).

Outward protection for cloth masks was extensively studied decades ago, and the results are highly relevant today. Compared with bacteria recovery from unmasked volunteers, a mask made of muslin and flannel reduced bacteria recovered on agar sedimentation plates by 99.3% to 99.9%, total airborne microorganisms by 99.5% to 99.8%, and bacteria recovered from aerosols (<4 μm) by 88% to 99% (6). A similar experiment in 1975 compared 4 medical masks and 1 commercially produced reusable mask made of 4 layers of cotton muslin (7). Filtration efficiency, assessed by bacterial counts, was 96% to 99% for the medical masks and 99% for the cloth mask; for aerosols (<3.3 μm), it was 72% to 89% and 89%, respectively.

In animal experiments, cloth masks prevented inward transmission of aerosolized tubercle bacilli. Inward protection was studied in rabbits exposed to droplet nuclei of tubercle bacilli (mostly aerosol-sized). Tightly fitting gauze masks with 3 or 6 layers were tested; the mean number of tubercles per rabbit was 28.5 in unmasked and 1.4 in masked animals, representing filtration efficacy of 95% ($P = 0.003$; our calculations) (8).

A single randomized controlled trial of cloth masks studied an unusually inefficient mask and compared it with medical masks rather than no mask. For influenza-like illness, the attack rate in health care workers wearing cloth masks was 2.3%, compared with 0.7% in health care workers wearing medical masks as indicated and 0.2% in the group wearing medical masks continuously (9). This trial has been misinterpreted as showing that cloth masks increase risk for influenza-like illness, but it actually provides no evidence on the effectiveness or harms of wearing cloth masks compared with not wearing cloth masks because it had no comparator group without masks. Furthermore, filtration efficiency for the cloth masks used in this study was 3% (9).

Whether wearing a mask of any sort in a community context protects oneself or others is unknown. An unpublished but rigorous rapid review of using medical masks to prevent transmission of influenza-like illness in nonmedical settings reported odds ratios between 0.81 and 0.95 for the effects studied, all with wide CIs crossing 1 (that is, no effect), in evidence that was graded as having low and very low quality (10).

When we apply the principles of evidence-based medicine to public policy, there is high-quality, consis-

Figure. Definitions of and relationship among FE, PF, and TIL.

Let c_{out} be the concentration of particles on the outside of the filter.

Let c_{in} be the concentration of particles on the inside of the filter.

The *filtration efficiency (FE)* of the filter is the ratio of particles removed by the filter; this is a number in the range $0 < FE < 1$. This is calculated by the formula:

$$FE = \frac{c_{out} - c_{in}}{c_{out}}$$

The *protection factor (PF)* of the filter is the ratio of particle concentration outside to inside; this is necessarily at least 1, and the higher the number, the better protection afforded by the filter. As a formula:

$$PF = \frac{c_{out}}{c_{in}}$$

These are related:

$$FE = \frac{c_{out} - c_{in}}{c_{out}} = 1 - \frac{c_{in}}{c_{out}} = 1 - \frac{1}{PF}$$

We also define the *total inward leakage (TIL)* to be a ratio of particles admitted by the filter. This is also in the range $0 < TIL < 1$.

$$TIL = \frac{c_{in}}{c_{out}}$$

Because a particle is either admitted by the filter or removed by the filter, it is apparent that

$$TIL + FE = 1$$

so

$$FE = 1 - TIL$$

Furthermore,

$$PF = \frac{1}{TIL}$$

For consistency, we calculated FE from data provided in the original work rather than presenting the data in the units chosen by the authors. "PF" and "fit factor" are synonyms. FE = filtration efficiency; PF = protection factor; TIL = total inward leakage.

tent evidence that many (but not all) cloth masks reduce droplet and aerosol transmission and may be effective in reducing contamination of the environment by any virus, including SARS-CoV-2. No direct evidence indicates that public mask wearing protects either the wearer or others. Given the severity of this pandemic and the difficulty of control, we suggest that the possible benefit of a modest reduction in transmission likely outweighs the possibility of harm. Reduced outward transmission and reduced contamination of the environment are the major proposed mechanisms, and we suggest appealing to altruism and the need to protect others. We recognize the potential for unintended consequences, such as use of formal personal protective equipment by the general public, incorrect use of cloth masks, or reduced hand hygiene because of a false sense of security; these can be mitigated by controlling the distribution of personal protective equipment, clear messaging, public education, and social pressure. Advocating that the public make and wear cloth masks shifts the cost of a public health intervention from society to the individual. In low-resource areas and for persons living in poverty, this is unacceptable. This could

be mitigated by public health interventions, with local manufacture and distribution of cloth masks based on materials and design informed by evidence.

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Acknowledgment: This work was created in part on the traditional territory shared between the Haudenosaunee confederacy and the Anishinabe nations, which was acknowledged in the Dish With One Spoon wampum belt. That wampum uses the symbolism of a dish to represent the territory and 1 spoon to represent that the people are to share the resources of the

land and take only what they need. The authors thank Melanie Chiarot, librarian, for her assistance in retrieving articles during a holiday period.

Disclosures: Disclosures can be viewed at www.acponline.org/authors/icmje/ConflictOfInterestForms.do?msNum=M20-2567.

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Ann Intern Med. doi:10.7326/M20-2567

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