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COVID-19 and non-traditional mask use: How do various materials compare in reducing the infection risk for mask wearers?

Running title: COVID-19 mask infection risk comparison

Amanda M. Wilson[1*], Sarah E. Abney[1,2], Marco-Felipe King[3], Mark H. Weir[1,4], Martín López-García[5], Jonathan D. Sexton[1], Stephanie J. Dancer[6,7], Jessica Proctor[3], Catherine J. Noakes[3], Kelly A. Reynolds[1]

1. Mel and Enid Zuckerman College of Public Health, University of Arizona, Tucson, AZ, USA
2. College of Agriculture and Life Sciences, University of Arizona, Tucson, AZ
3. School of Civil Engineering, University of Leeds, Woodhouse Lane, LS29JT, Leeds, UK
4. College of Public Health, The Ohio State University, Columbus, OH, USA
5. School of Mathematics, University of Leeds, Woodhouse Lane, LS29JT, Leeds, UK
6. School of Applied Sciences, Edinburgh Napier University, Edinburgh, UK
7. Department of Microbiology, Hairmyres Hospital, NHS Lanarkshire, G758RG, UK

*Please address correspondence to Amanda M. Wilson, apfeifer@email.arizona.edu, 1295 N. Martin Ave. Drachman Hall PO Box 245210, Tucson, AZ

The SARS-CoV-2 pandemic has increased demands for surgical and respirator masks for healthcare workers (HCWs) and other frontline staff. The debate over the importance of airborne transmission of SARS-CoV-2 continues, but SARS-CoV-2 has been detected in air and laboratory studies demonstrate viability >12 hours in aerosols [1–3]. Low sampling volumes, air outlet fan location, and potential virus damage during sampling may explain SARS-CoV-2 detection variability [1,3].

Limited mask supply creates a risk for HCW exposure to SARS-CoV-2. Non-traditional materials are widely recommended for public use (source control) and have been considered in place of regulated masks in healthcare, especially in social-care settings. While various materials are effective for filtering large droplets, aerosols generated from sneezing, coughing, and aerosol-generating procedures may more readily pass through materials or leakage points [4]. There is a small amount of data on filtration efficacy but currently no quantitative modelling of efficacies for infection risk reduction.

We developed a probabilistic model to estimate infection risks for short (30-second, brief patient check) and long (20-minute, the duration required for patient intubation) inhalation exposure scenarios. These included situations in a COVID-19 patient room in which no mask was worn; an FFP2 (N95), FFP3 (N99) respirator or surgical mask was worn; or a non-traditional material mask (silk, tea towel, vacuum cleaner bag, pillowcase, antimicrobial pillowcase, cotton mix, 100% cotton t-shirt, linen, and scarf) was worn.

Inhaled viral dose was estimated using published concentrations (RNA/m^3) of SARS-CoV-2 for >4 and 1-4 μm droplets measured in a hospital setting [1]. We used ranges from reported concentration data originating from a symptomatic and an asymptomatic patient to calculate minimum and maximum of randomly sampled uniform distributions [1]. Viral exposure for these two size ranges were summed to estimate a total inhaled dose. Doses were estimated for three assumed infectious fractions of total detected viral RNA: 0.1%, 1%, and 10%. Inhaled volumes (m^3) were estimated using inhalation rates for men and women, where 5th and 99th percentiles of inhalation rates offered the uniform distribution minimum and maximum, respectively [5].

Filtration efficacies (fraction of total virus filtered out by the material) were used to model the reduction in viral inhalation exposure per material type. Due to lack of particle size-specific filtration efficacy data for these materials, we assumed filtration efficacy distributions were applicable to both particle size ranges. For each 10,000 combinations investigated, a filtration efficacy was randomly sampled from a normal distribution, left- and right-truncated at 0 and 1, respectively. For surgical mask and non-traditional materials, mean and standard deviations of efficacies were informed by MS2 filtration efficacies [6]. Mean efficacies of 95% and 99% were assumed for FFP2 and FFP3 respirators, respectively. SDs were provided by Rengasamy et al. (2009), where larger SDs of two manufacturer versions were chosen as a conservative risk approach [7].

Data from SARS-CoV-1 and human coronavirus 229E (HCoV-229E) dose-response curves were used to estimate a SARS-CoV-2 exact beta-Poisson curve [8]. Based on current epidemiological knowledge, we assume the infectivity of SARS-CoV-2 lies between SARS-CoV-

1 and HCoV-229E. Pairs of bootstrapped α and β values were used to estimate infection risk per dose.

Comparing no protection (baseline) for 20-minute and 30-second exposures, we predicted that mean infection risks were reduced by 24 - 94% and by 44 - 99% depending on the mask. Risk reductions decreased as exposure durations increased. The greatest reduction in estimated mean infection risk was for FFP3 masks, which as expected reduced baseline mean risks by 94% and 99% for 20-minute and 30-second exposures, respectively (Figure 1). Of non-traditional materials, the vacuum cleaner bag resulted in the greatest reduction in mean infection risk (20-minute exposure: 58%, 30-second exposure: 83%), while scarves offered the lowest (20-minute exposure: 24%, 30-second exposure: 44%) (Figure 1). However, large filtration variability, such as for silk or the tea towel, should be considered when comparing non-traditional mask materials (Figure 1).

Limitations include not accounting for viral transfer from the hands to the mask during mask adjustments and assuming all masks were worn in the same way. Realistically, homemade mask fit is likely to be more variable than for regulated masks. While the HCoV-229E data utilized for the dose-response curve was based on human data, the SARS-CoV-1 dose-response data originated from an animal-feeding study [8]. Future work includes updating the dose-response curve as data on SARS-COV-2 emerges and addressing the effects of design/fit on infection risk.

We demonstrate that some materials, like vacuum cleaner bags, may be effective alternatives for reducing infection risk. While N95 masks (and similar respirators) are recommended for HCWs and others in close proximity to aerosol generating procedures, alternative materials may be useful where there are PPE shortages. This may be of particular relevance in low resource settings where access to PPE is considerably more limited.

Code, Materials

Under a Creative Commons Zero v1.0 Universal license (CC-BY), code can be accessed at: https://github.com/awilson12/COVID-19-Mask-Note

Conflicts of Interest

The authors have no conflicts of interest to declare.

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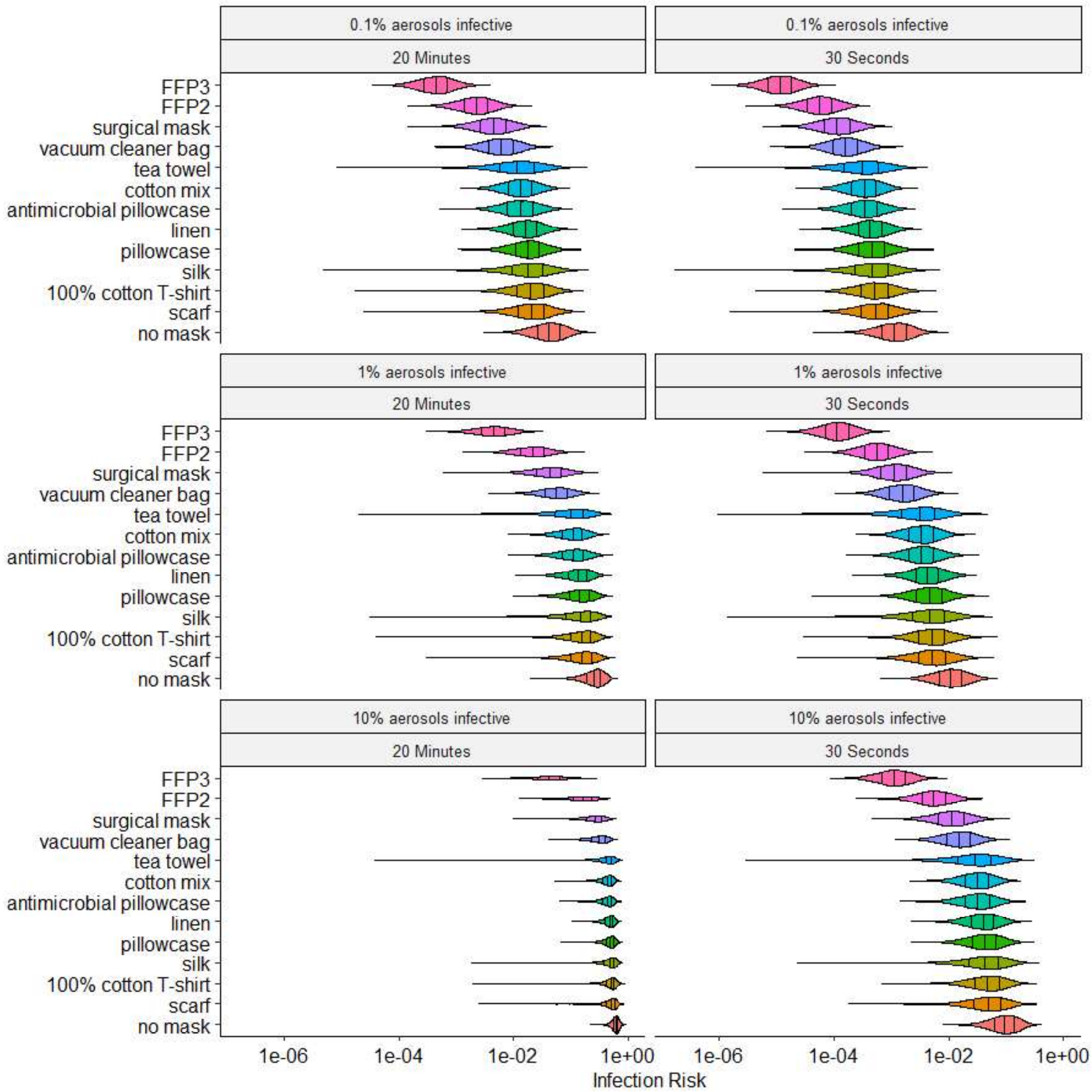
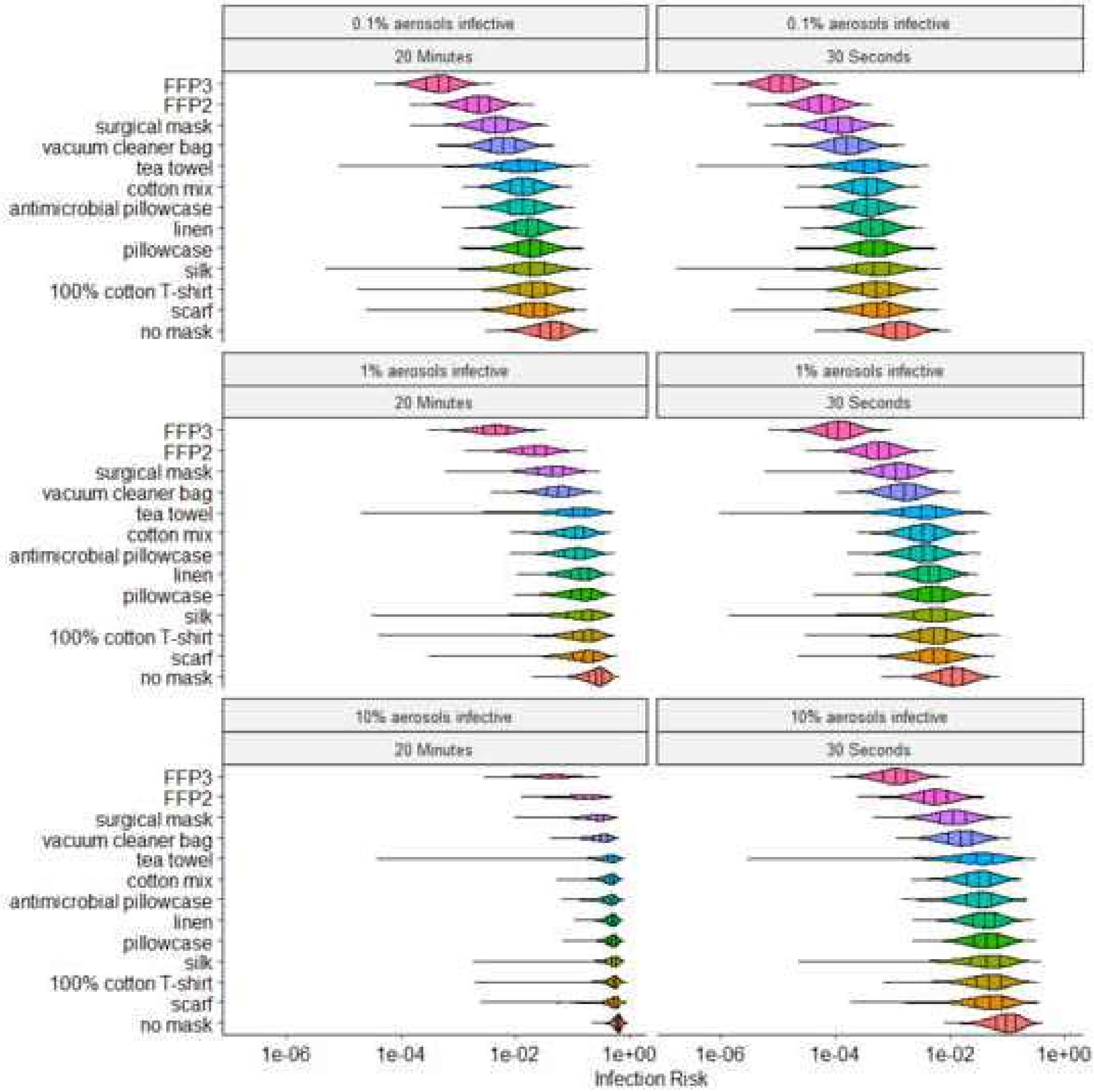


Figure 1. Distributions of estimated infection risks for FFP3, FFP2, surgical masks, masks made of non-traditional materials (vacuum cleaner bag, tea towel, cotton mix, antimicrobial pillowcase, linen, pillowcase, silk, 100% cotton T-shirt, scarf) and no mask for 30 seconds (0.5 minutes) or 20 minutes of inhalation exposure*

*Vertical lines indicate the 25th, 50th, and 75th infection risk percentiles

Figure


0.1% aerosols infective
20 Minutes
30 Seconds
1% aerosols infective
10% aerosols infective
FFP3
FFP2
surgical mask
vacuum cleaner bag
tea towel
cotton mix
antimicrobial pillowcase
linen
pillowcase
silk
100% cotton T-shirt
scarf
no mask
1e-06
1e-04
1e-02
1e+00
Infection Risk