RESEARCH LETTER

Fitted Filtration Efficiency of Double Masking During the COVID-19 Pandemic

Although global vaccination efforts against SARS-CoV-2 are underway, the public is urged to continue using face masks as a primary intervention to control transmission.[1] Recently, US public health officials have also encouraged doubling masks as a strategy to counter elevated transmission associated with infectious SARS-CoV-2 variants.[2] US Centers for Disease Control and Prevention investigators reported that doubling masks increased effectiveness, but their assessment was limited in type and combinations of masks tested, as well as by the use of head forms rather than humans. To address these limitations, this study compared the fitted filtration efficiency (FFE)[3,4] of commonly available masks worn singly, doubled, or in combinations.

Methods | Face-covering FFE was measured on 1 female volunteer (weight, 53 kg; height, 160 cm; head circumference, 56.0 cm) and 2 male volunteers with shaven faces (weight, 75 kg; height, 178 cm; head circumference, 58.5 cm; and weight, 76 kg; height, 175 cm; head circumference, 55.9 cm, respectively), as described previously.[3,4] In brief, FFE corresponds to the concentration of particles behind the mask expressed as a percentage of the particle concentration in a sodium chloride particle-enriched chamber atmosphere [FFE% = 100 × (1 − behind the mask particle concentration/ambient particle concentration)] measured during a series of repeated movements of the torso, head, and facial muscles as outlined by the Occupational Safety and Health Administration Quantitative Fit Testing protocol. Chamber temperatures were 22 °C to 24 °C, and relative humidities were 42% to 52%. For the doubling of each procedure and cloth mask tested, the same mask worn singly served as a control. For all cloth-procedure mask combinations, the same procedure mask (Intco) was used for all, with the single cloth mask serving as the control. The institutional review board at the University of North Carolina at Chapel Hill waived the need for study approval as well as individual consent needed for device testing.

Results | As shown in the **Table**, procedure masks worn singly by study volunteers showed a range of mean (SD) FFE between 43% (2%) and 62% (11%). On average, across all masks and volunteers, adding a second procedure mask improved mean (SD) FFE from 55% (11%) when single masking to 66% (12%) when double masking. Single cloth masks performed less efficiently (mean [SD] FFE range, 41% [12%] to 44% [12%]) than the procedure masks. Doubling a cotton mask improved FFE but could reduce breathability.

Although adding a procedure mask (mean [SD] FFE, 61% [13%]) over the cloth masks provided modest increases in their FFE (mean [SD] range, 55% [10%] to 60% [14%]), the overall performance was no different than wearing the procedure mask by itself. In contrast, wearing a procedure mask under the cloth face covering produced marked improvements in overall FFE (mean [SD] range, 66% [5%] to 81% [6%]).

Discussion | Disposable medical procedure masks are commonly worn in health care and public settings during the COVID-19 pandemic. The FFE for procedure masks is generally below that of high-efficiency N95 respirators certified by the US National Institute for Occupational Safety and Health and foreign-sourced equivalents (eg, KN95).[4] However, many

Table. Fitted Filtration Efficiency (FFE) of Face Masks Tested in 1 Female and 2 Male Volunteers[a]

Face mask	FFE, mean (SD), %		
	Single mask	Double mask	Difference
Procedure ear-loop masks			
Medline	53 (8)	68 (16)	14 (15)
Henry	62 (11)	74 (4)	12 (7)
Shine Ya	43 (2)	55 (10)	12 (8)
Intco	61 (13)	66 (9)	4 (12)
Cloth masks			
Hanes cotton ear-loop mask	44 (12)	57 (14)	14 (4)
Procedure mask worn over	NA	59 (18)	16 (10)
Procedure mask worn under	NA	66 (5)	23 (12)
Cotton bandana	44 (4)	NA	NA
Procedure mask worn over	NA	55 (10)	11 (8)
Procedure mask worn under	NA	77 (10)	33 (10)
Polyester gaiter	41 (12)	NA	NA
Procedure mask worn over	NA	60 (14)	19 (7)
Procedure mask worn under	NA	81 (6)	40 (6)

Abbreviation: NA, not applicable.

[a] The FFE percentage corresponds to 100 × (1 − behind the mask particle concentration/ambient particle concentration). Overall FFE percentage was calculated across the length of the testing protocol. For all mask-doubling comparisons, the absolute improvement was calculated by subtracting the FFE of the single control mask from the combination doubled mask.

procedure masks available to the public are constructed with nonwoven polypropylene, the same highly efficient filtering medium used in respirators. In fact it is notable that enhancements that improve the seal between the mask and the facial skin dramatically improve FFE performance,[3] suggesting that fit, not material, is the intrinsic limiting factor for procedure masks.

Results of this quality improvement study demonstrated that wearing a medical procedure mask underneath a cloth mask provided the best improvement to FFE of all the combinations evaluated. The improvement in the FFE of procedure masks when doubled or when worn underneath reusable cloth face coverings is consistent with minimizing leaks between the mask and facial skin, including the bridge of the nose. Limitations of this study are that we tested only 1 type of procedure mask and that 3 volunteers participated in the doubling evaluations. However, despite some between-volunteer variation, the present results support the overall conclusion that double masking improves FFE.

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