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Brief Report

Cloth Mask with Window as an Alternative to Opaque Mask for Students with Speech, Language, and Hearing Deficits for Infection Risk Mitigation

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ABSTRACT

Introduction. Visualization of oral movements and facial expressions is essential for learning, development, and communication, especially among students receiving speech and language services. This study aimed to assess the effectiveness of cloth masks with transparent windows as an alternative to opaque masks in mitigating the risk of droplet-transmitted infectious diseases.

Methods. Researchers measured the filtration efficiency of various medical and non-medical masks, both with and without transparent windows. A testing pipe, fitted with the selected masks, was used to deliver particulate matter (PM) at an airflow velocity mimicking human breathing. Particle size and airflow were measured using three real-time particle monitors positioned upstream and downstream of the masks. Filtration efficiency was then calculated for each of the eight masks.

Results. Mask efficiency varied based on build quality and material. Filtration efficiency for the four face masks with transparent windows ranged from 28.6% to 90%, with the single-layer mask performing the worst. All multi-layer masks with windows achieved filtration efficiencies greater than 70% for all particle sizes tested (1, 2.5, and 10 microns), exceeding that of the opaque cotton masks and approaching the filtration levels of surgical masks.

Conclusions. Given the high filtration efficiency of cloth masks with transparent windows, the authors conclude that these masks can reduce the transmission of SARS-CoV-2 and other droplet-transmitted infectious diseases while also improving communication for individuals with speech, language, and/or hearing impairments.

INTRODUCTION

The COVID-19 pandemic impacted education worldwide, with many schools closing and others having to adapt rapidly. Students with exceptionalities, such as those requiring speech and language instruction (SLI), often were left without access to specialized services. Given that nearly one-fifth of students with academic exceptionalities receive SLI, and 10% of Kindergarten through 12th grade (K-12) students are English Learners (ELs), the absence of SLI services during the pandemic was particularly concerning.[1,2] Due to the broad implications of school shutdowns, especially for marginalized and minority students, as well as those receiving special education services,[3-5] numerous organizations advocated for in-person learning with appropriate infection risk mitigation measures.[6-9]

Masking mandates became common in schools, with data showing reduced disease transmission among mask-wearers.[10] This aligned with existing literature indicating that masks decrease the risk of transmission for other droplet-transmitted infectious diseases such as influenza and tuberculosis.[11-13] As the education system moves forward post-pandemic, it is crucial to protect both students and educators from infectious diseases while ensuring equitable access to education for students requiring SLI.

SARS-CoV-2 is primarily spread through respiratory droplets, with larger particles typically traveling 1-2 meters from the source before settling. However, environmental factors (e.g., temperature, humidity, airflow) can cause larger droplets (100 μm diameter) to evaporate and shrink into smaller particles, known as droplet nuclei (<5 μm diameter), which allow for aerosol transmission. These droplet nuclei remain airborne longer (8 minutes to 41 hours) and can travel farther, potentially infecting others.[14,15]

During the pandemic, universal masking became a key strategy for preventing COVID-19.[16-18] Medical professionals primarily use N95 masks and Level 1 surgical masks. N95 masks are designed to filter out more than 95% of particles 0.3 microns or larger but can actually filter up to 99.8% of particles as small as 0.1 microns.[19] Surgical masks, though less efficient and more variable than N95s for smaller particles, still offer good protection.[19] Cloth masks, while variable in filtration, can perform comparably to surgical masks in some cases and were recommended for non-medical use during the pandemic due to their accessibility and reusability.[17,19,20]

Although masks are effective at reducing disease transmission, they can have unintended consequences for speech and language development and education. Since the visualization of oral movements and facial expressions is critical for EL and SLI students, traditional masks that cover much of the face can hinder communication for this population.[21,22] An alternative is face masks with transparent windows (FMTWs), which allow for better visualization of oral movements and expressions during communication. However, given their recent development, there is limited evidence on the filtration effectiveness of FMTWs.

This study aimed to evaluate whether FMTWs effectively filter respiratory droplets, making them a suitable alternative to standard masks for SLI students during infectious disease outbreaks.

METHODS

Target Particle Size. Previous research has shown that particles from a human sneeze range in size from 100 μm to 1000 μm,[23] large enough to carry respiratory pathogens such as measles (0.05-0.5 μm), influenza (0.1-1 μm), and *Mycobacterium tuberculosis* (1-3 μm). For this study, particles with diameters of 1 μm, 2.5 μm, and 10 μm were chosen to test the effectiveness of various face masks.[24]

The experimental procedure consisted of three main steps: (1) particle generation, (2) measuring particle size with and without face masks, and (3) measuring airflow rate. Aerosols were generated by burning multiple incense sticks to create a well-mixed and stable condition in the generating chamber. Once the incense sticks were lit, a fan was used to direct airflow through the chamber's air inlet. The upstream particle concentration, with airflow, was measured and remained stable in the range of 600–800 μg/m^3, confirming steady conditions. The generated aerosols were then diluted with clean air and delivered to the testing pipe at an airflow speed of 1.5 m/s, simulating the breathing velocity of healthy adults.[25]

To calculate mask effectiveness, two real-time particle monitors (OPC-N3, Alphasense, UK) were used to measure aerosol particles both upstream (Figure 1, location A) and downstream (Figure 1, location B) of the face mask.

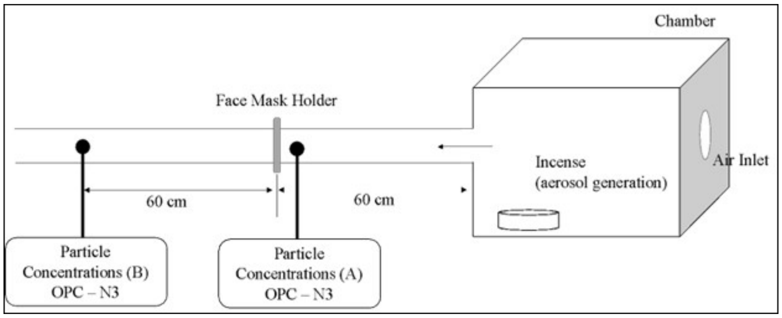

Figure 1. Experimental setup for the rapid screening test.

An Extech anemometer was used to measure airflow rates. Air velocity was measured both upstream and downstream to compare flow rate changes with and without masks. The filtration efficiency of each mask was calculated by comparing the particle concentrations at the upstream and downstream locations. The below equation was used:

$$\textit{Filter Efficiency (\%)} = (1 - C_{downstream}/C_{upstream}) \times 100$$

$C_{downstream}$: Particle concentrations at the downstream of the face mask

$C_{upstream}$: Particle concentrations at the upstream of the face mask

Theory and Calculation. Filtration efficiency is expressed as the percentage of particles captured and retained by a filter medium.[26] In this study, the filtration efficiency of the masks was calculated to evaluate effectiveness in capturing aerosols generated during speaking and coughing.

RESULTS

As shown in Figure 2, eight selected masks were tested: N-95 mask (A), medical grade Level 1 surgical mask (B), and two different double layered cotton masks (C, D) were used as a reference (Table 1). Four different types of cloth FMTWs (E, F, G, and H) were used. All were installed on the mask holder and measured for at least 10 minutes.

Figure 2. Selected face masks.

Table 1 shows the mean and standard deviation (SD) of filter efficiency for the eight masks tested. Mask A (N-95) showed >99 % filter efficiency of all particles. Mask C had the lowest filter efficiency (14.7 – 41.7 %). The filter efficiencies of the four FMTWs (Masks E through H) varied from 28.6% to 90%. Overall, the lowest filter efficiency was shown when calculated based on PM 1 concentrations. Fabric and stitch type connecting the cloth to the window may have affected filter efficiency. Figure 2 shows a closer look of the four FMTWs. They all use the same stitch type, but face mask F has a double line with a large window. These two factors reduce the likelihood of particle leakage and increase filter efficiency. Mask E had the lowest filter efficiency and is the only tested mask with a single layer of fabric; it also has a single line stitch.

Table 1. Filter efficiency for masks with and without a clear window (per different size particles).

Face Mask	Material/Face Mask	Filter Efficiency (%) (SD)		
		PM 1*	PM 2.5*	PM 10*
A	N-95	99.4 (0.6)	99.6 (0.4)	99.7 (0.4)
B	Medical grade Level 1 surgical mask	83.6 (2.5)	86.6 (2.2)	87.9 (2.2)
C	Double layer cotton face mask #1	14.7 (5.2)	33.4 (6.1)	41.7 (7.3)
D	Double layer cotton face mask #2	53.0 (2.8)	73.1 (1.9)	79.5 (1.5)
E	Single-layered cloth mask with transparent window #1- polyester fabric	28.6 (5.7)	39.3 (7.3)	49.0 (7.2)
F	Multi-layered cloth mask with transparent window #2	87.2 (3.0)	89.6 (3.4)	90.0 (3.6)
G	Multi-layered cloth mask with transparent window #3	78.2 (5.3)	84.6 (3.9)	86.8 (3.2)
H	Multi-layered cloth mask with transparent window #4 - Home-made 2-layer 100% cotton fabric with 2-layer food grade storage bag window	75.1 (6.0)	81.0 (5.5)	82.8 (5.9)

*PM: Particulate matter

DISCUSSION

The goal of this study was to assess if FMTWs were comparable to other masks in filtering respiratory droplets. Three (F, G, H) of four FMTWs tested demonstrated comparable protection to double-layered cotton masks and the level 1 surgical mask. This suggests lab-based non-inferiority of FMTWs to multi-layered cloth masks for community-wide and school-based non-pharmaceutical COVID-19 mitigation strategies. Moreover, FMTWs may provide enhanced protection compared to double-layered cotton masks while also providing an increased advantage for communication. Interpreting results is more challenging for FMTWs due to their heterogeneous makeup. For example, mask F had a larger plastic window, limiting the cloth portion in the testing apparatus and complicating its results. Regardless, all multilayer FMTWs performed comparably to standard cloth masks and some approached filter efficiency of the surgical mask suggesting that these masks are effective in filtering respiratory droplets carrying infectious particles.

Results showed a large discrepancy in the filter efficiency of the two double-layered cotton masks (C, D) and the first FMTW (E) as compared to the subsequent three FMTWs (F, G, and H). This suggests that not all masks are created equally as materials and build quality may affect filtration efficiency. Across communities, masks have a variety of designs, materials, layers, and quality but despite differences evidence has shown the community health benefit of universal masking in the prevention of SARS-CoV-2 transmission.[10] In individual interactions, high quality, well-fitting masks that have a high filter efficiency are likely to be superior.

When working closely with students receiving SLI, it is important to use the mask that will provide the best protection from disease transmission and interfere the least with communication and learning. This research suggests that FMTWs will work well for these interactions by decreasing disease transmission and allowing visualization of oral movement and expression. FMTWs should also be considered for all types of instruction to young children as they are learning language and social development. When creating and manufacturing these masks, it is important to use multiple layers of cloth to surround the transparent window. There also may be benefit from a tighter or double stich pattern.

This study measured filter efficiency of a variety of masks. The measurements obtained for the medical masks are comparable to other reported filter efficiency studies. Still, there are limitations when applying these results to the prevention of SARS-CoV-2 and other droplet-transmitted infectious diseases. Mask efficacy is dependent on fit and compliance. This study did not assess how mask type may affect compliance or other potential difficulties with the transparent window such as fogging and saliva disrupting visualization through the window. In addition, comfort, oxygenation, and effect of chronic illness was not assessed in this study. Further studies should consider evaluating comfort, compliance, appropriate wear, and feasibility of prolonged wear of FMTWs.

REFERENCES

[1] Hussar B, Zhang J, Hein S, et al. The Condition of Education 2020 (NCES 2022-144). U.S. Department of Education. Washington, DC: National Center for Education Statistics. 2020. https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2020144. Accessed March 1, 2024.
[2] Snyder TD, De Brey C, Dillow SA. Digest of Education Statistics 2018 (NCES 2020-009). National Center for Education Statistics. 2019. https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2020009. Accessed March 18, 2024.
[3] Golden AR, Srisarajivakul EN, Hasselle AJ, Pfund RA, Knox J. What was a gap is now a chasm: Remote schooling, the digital divide, and educational inequities resulting from the COVID-19 pandemic. Curr Opin Psychol 2023; 52:101632. PMID: 37437380.
[4] Colvin MK, Reesman J, Glen T. Altered trajectories: Considering the long-term impact of educational disruption during the COVID-19 pandemic on neurodevelopment and a call to action for neuropsychology. Arch Clin Neuropsychol 2024; 39(3):305-312. PMID: 38520379.
[5] Goldberg S (Office for Civil Rights). Education in a Pandemic: The Disparate Impacts of COVID-19 on America's Students. U.S. Department of Education. 2021. https://www2.ed.gov/about/offices/list/ocr/docs/20210608-impacts-of-covid19.pdf. Accessed May 24, 2024.
[6] Executive Order on Supporting the Reopening and Continuing Operation of Schools and Early Childhood Education Providers. The White House. 2021. https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/21/executive-order-supporting-the-reopening-and-continuing-operation-of-schools-and-early-childhood-education-providers/. Accessed May 24, 2024.
[7] Kansas COVID Workgroup for Kids Recommendations for the 2021-2022 School Year. 2021. http://www.kansasaap.org/wordpress/wp-content/uploads/2021/07/KCWK-School-Recommendations-2021-2022-7-16-2021.pdf. Accessed May 24, 2024.
[8] Maiers S. Press Release: Pediatricians, educators and superintendents urge a safe return to school this fall. 2020. https://www.nea.org/about-nea/media-center/press-releases/pediatricians-educators-and-superintendents-urge-safe-return-school-fall. Accessed May 24, 2024.
[9] Cowling BJ, Zhou Y, Ip DK, Leung GM, Aiello AE. Face masks to prevent transmission of influenza virus: A systematic review. Epidemiol Infect 2010; 138(4):449-456. PMID: 20092668.
[10] Boutzoukas AE, Zimmerman KO, Inkelas M, et al. School masking policies and secondary SARS-CoV-2 transmission. Pediatrics 2022; 149(6):e2022056687. PMID: 35260896.
[11] Dharmadhikari AS, Mphahlele M, Stoltz A, et al. Surgical face masks worn by patients with multidrug-resistant tuberculosis: Impact on infectivity of air on a hospital ward. Am J Respir Crit Care Med 2012; 185(10):1104-1109. PMID: 22323300.
[12] Zhang L, Peng Z, Ou J, et al. Protection by face masks against Influenza A(H1N1)pdm09 virus on trans-pacific passenger aircraft, 2009. Emerg Infect Dis 2013; 19(9):1403-1410. PMID: 23968983.
[13] MacIntyre CR, Chughtai AA. Facemasks for the prevention of infection in healthcare and community settings. BMJ 2015; 350:h694. PMID: 25858901.
[14] Cai J, Sun W, Huang J, Gamber M, Wu J, He G. Indirect virus transmission in cluster of COVID-19 cases, Wenzhou, China, 2020. Emerg Infect Dis 2020; 26(6):1343-1345. PMID: 32163030.
[15] Jang S, Han SH, Rhee JY. Cluster of coronavirus disease associated with fitness dance classes, South Korea. Emerg Infect Dis 2020; 26(8):1917-1920. PMID: 32412896.
[16] Perencevich EN, Diekema DJ, Edmond MB. Moving personal protective equipment into the community. JAMA 2020; 323(22):2252-2253. PMID: 32347911.
[17] Centers for Disease Control and Prevention (CDC). 2019. https://www.cdc.gov/coronavirus/2019-ncov/index.html. Accessed March 18, 2024.
[18] Van Dyke ME, Rogers TM, Pevzner E, et al. Trends in county-level COVID-19 incidence in counties with and without a mask mandate - Kansas, June 1-August 23, 2020. MMWR Morb Mortal Wkly Rep 2020; 69(47):1777-1781. PMID: 33237889.
[19] Rengasamy S, Shaffer R, Williams B, Smit S. A comparison of facemask and respirator filtration test methods. J Occup Environ Hyg 2017; 14(2):92-103. PMID: 27540979.
[20] Konda A, Prakash A, Moss GA, Schmoldt M, Grant GD, Guha S. Aerosol filtration efficiency of common fabrics used in respiratory cloth masks. ACS Nano 2020; 14(5):6339-6347. PMID: 32329337.
[21] Arnold P, Hill F. Bisensory augmentation: A speechreading advantage when speech is clearly audible and intact. Br J Psychol 2001; 92(2):339-355. PMID: 11417785.

22. Atcherson SR, Mendel LL, Baltimore WJ, et al. The effect of conventional and transparent surgical masks on speech understanding in individuals with and without hearing loss. J Am Acad Audiol 2017; 28(1):58-67. PMID: 28054912.
23. Han ZY, Weng WG, Huang QY. Characterizations of particle size distribution of the droplets exhaled by sneeze. J R Soc Interface 2013; 10(88):20130560. PMID: 24026469.
24. Schilling K, Gentner D, Wilen L, et al. An accessible method for screening aerosol filtration identifies poor-performing commercial masks and respirators. J Expo Sci Environ Epidemiol 2021; 31(6):943-952. PMID: 32764709.
25. Tang JW, Nicolle AD, Klettner CA, et al. Airflow dynamics of human jets: Sneezing and breathing - Potential sources of infectious aerosols. PLoS ONE 2013; 8(4):e59970. PMID: 23560060.
26. Hinds WC, Zhu Y. Aerosol technology: Properties, behavior, and measurement of airborne particles. Third Edition. Hoboken, New Jersey: John Wiley & Sons, 1999. ISBN: 9781119494041.

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