Cloth Face Mask Fit and Functionality for Children 4-6 Years Old

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Introduction As of March 24, 2021, the number of children under 18 years of age infected by the COVID-19 coronavirus disease reached 2.6 million with a total of 321 deaths in the U.S. (Center for Disease Control, n.d.-b). When fitted snugly, face masks provide increased source control of expelled droplets that may carry infectious particles, thereby limiting virus transmission (Center for Disease Control, n.d.-a). While medical equipment such as surgical masks and N-95 respirators are prioritized for healthcare professionals and workers on the front lines, items such as cloth face masks have become essential for most of the population, including children. These masks have recently been shown to elevate the relative humidity of inspired air, linked to a decrease in disease severity (Courtney & Bax, 2021). Thus, cloth face coverings can act not only as source control devices but also provide an additional level of protection to the wearer. Design and testing standards of barrier face coverings for adults are outlined in ASTM F3502-21 and AATCC M14-2020, but do not include consideration for children to date. Children's facial proportions and respiratory rates are significantly different than adults (Farkas et al., 1992; Lin et al., 2010; Lockett, 2019), and thus face masks designed for adults that are sized down for younger populations may not fit children as expected. Limited research has been conducted using commonly available fabric in nonmedical face masks and has excluded children's breathing rates for testing parameters (Konda et al., 2020; van der Sande et al., 2008). While the CDC and World Health Organization (WHO) have issued basic guidelines on the use of face masks in children, the information is inconsistent and may be confusing for the public as there is ambiguity between recommended age and number of mask layers, and it is thus important to research this area further. Commercially available children's cloth masks range widely in material type, filtration, fabric structures, methods of construction, layering, and shape, with a lack of sizing systems, anthropometric data or guidelines specifically targeting the fit assessment and design of cloth face masks for children 4-6 years old. Thus, this study aimed to investigate consumer insights into children's face mask attributes, analyze the fit of commercially available children's masks, examine the impact of face mask material properties on performance, and identify design considerations for improved functionality as source control devices.

Methods A multi-method approach was used to address the goals of this study. An IRB-approved Qualtrics survey was conducted online to better understand consumer's experiences with commercial face masks and preferred mask attributes. A content analysis of commercially available children's face masks was conducted by two apparel designers, with 8 masks selected across a range of fiber/fabric types, number of layers, styles, size adjustability, and use of filters, for observations of wear and fit, and filtration efficiency (FE) analysis. Due to difficulty in recruiting children during the global pandemic, three children ages five (n=2, one boy and one girl) and six (n=1, boy) years old from the researchers' families tested a selection of face masks

indoors and outdoors, with IRB exemption approval. Of the three participants, the 6-year-old boy Size 7 and a head form in size 8R (based on ASTM D6458-12) 3D printed from the scan of a six-year-old boy from Size North America dataset were included in the fit analysis. The selection of the scan was based on 3D-printability of the ears in consideration of all the head anthropometry data in a normative band. The two heads were scanned with a Structure sensor, capturing their faces with and without wearing the eight purchased commercial face masks. Visual fit analyses then conducted by two researcher expert-judges evaluated set and ease using a 5-point Likert-type rating scale (1=too tight, 3=good fit, 5=too loose). Face masks patterns were traced and imported to Adobe Illustrator and ImageJ to illustrate the nested patterns and obtain their surface area. Chi-square non-parametric test were used for statistical analysis with JMP Pro 15.0.0 software. Fabric performance for breathability and FE was evaluated on deconstructed mask samples. Multilayer samples were assembled in the sequence of the original mask. Air permeability was measured following ASTM D737-18. A simulated breathing apparatus consisting of a large animal respirator, aerosol generator, filter holder, and multi-channel particle counter was employed to assess the exhaled aerosol capture of 0.3 μm, 0.5 μm, and 1.0 μm sized particles by the various flat fabric samples. Samples were weighed by their individual layers before testing, directly after testing (wet), and 24 hours after testing (dry). Wet Pickup was calculated as a ratio of the difference between the wet and dry weights and the initial weight.

Results, Discussion, and Conclusion Results of this study indicate issues with the fit, filtration, size, wear, and comfort of masks for children ages 4-6 including poor overall fit leading to slippage from proper positioning and fogging of glasses, thermal and ear discomfort, and difficulty with donning/doffing. From the market research and Qualtrics survey, the most common mask attributes were a shaped style, stretch ear loops, two layers of woven cotton, and an all-over surface print. Masks with a fitted shape around the nose, mouth and under chin coverage were most preferred, and those with highest coverage area were found to provide better fit based on results from the structured set and ease analysis of scanned heads. Evaluation of FE and air permeability showed a weak correlation between aerosol capture and breathability. No significant difference in wet pickup was measured between masks made of hydrophobic materials and masks made of hydrophilic materials, except for the 3-layered tightly woven cotton poplin mask. A balance between breathability and FE is impacted by the types of mask materials and number of layers, including moisture retention against the wearer's face, overall thermal comfort, and protection. Concerns of poor fit, comfort, and breathability among commercially available children's face masks are consistently indicated by these collective results. For the fit analysis portion of the study, the results cannot be generalizable due to the limited number of test subjects. Nonetheless, these findings emphasize the importance of future studies for updating sizing systems for children's face mask development to accommodate for young children's facial measurements and proportions including width, length, depth, and ease. Future studies should also investigate special design considerations for children's face masks including limited dexterity, higher respiration rates, and careful attention to fastenings in relation to donning, doffing, and interference with glasses and hair.

References

American Association of Textile Chemists & Colorists. (2020). AATCC M14, Guidance and Considerations for General Purpose Textile Face Coverings: Adult.

ASTM International. (2021). *F3502-21 Standard Specification for Barrier Face Coverings*. https://doi.org/10.1520/F3502-21

Center for Disease Control. (n.d.-a). *Considerations for wearing masks*. Retrieved December 7, 2020 from https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/cloth-face-cover-guidance.html

Center for Disease Control. (n.d.-b). *Demographic Trends of COVID-19 cases and deaths in the US reported to CDC*. Retrieved March 24, 2021 from https://covid.cdc.gov/covid-data-tracker/#demographics

Center for Disease Control. (2021). Health Department-Reported Cases of Multisystem Inflammatory Syndrome in Children (MIS-C) in the United States Retrieved March 09, 2021 from https://www.cdc.gov/mis-c/cases/index.html

Courtney, J. M., & Bax, A. (2021). Hydrating the respiratory tract: an alternative explanation why masks lower severity of COVID-19. *Biophysical journal*, *120*(6), 994–1000. https://doi.org/10.1016/j.bpj.2021.02.002

Farkas, L. G., Posnick, J. C., & Hreczko, T. M. (1992). Anthropometric growth study of the head. *The Cleft Palate-Craniofacial Journal*, *29*(4), 303-308.

Konda, A., Prakash, A., Moss, G. A., Schmoldt, M., Grant, G. D., & Guha, S. (2020). Aerosol filtration efficiency of common fabrics used in respiratory cloth masks. *ACS nano*, *14*(5), 6339-6347.

Lin, A. J., Lai, S., & Cheng, F. (2010). Growth simulation of facial/head model from childhood to adulthood. *Computer-Aided Design and Applications*, *7*(5), 777-786.

Lockett, E. (2019). *What is a normal respiratory rate for kids and adults?* Healthline. Retrieved January 15, 2021 from https://www.healthline.com/health/normal-respiratory-rate

van der Sande, M., Teunis, P., & Sabel, R. (2008). Professional and home-made face masks reduce exposure to respiratory infections among the general population. *PloS one*, *3*(7), e2618.