SUBJECT: Quantitative Respirator Fit Testing of HensMask
AUTHORS: Jenni Buckley, Mike Gladle, Krista Murray, Whitney Sample
AFFILIATIONS: University of Delaware, Environmental Health & Safety & Dept. Mechanical Engineering
DATE: April 15th, 2020

INTRODUCTION

The COVID-19 pandemic has stressed the global supply chain for clinically-rated N95 face masks. While much of this shortage can be attributed to exceptionally high demand coupled with a steep slowdown in production, the widespread use of medical-grade face masks by the general public has also limited supply for medical providers. Now with the CDC recommending use of face masks for even brief excursions outside of the home, demand for face masks from the general public may continue to stress the medical supply chain even as overseas manufacturers come back online. The CDC and news media have launched a concerted effort to encourage the general public to use "do-it-yourself" (DIY) face mask designs, e.g., sewn masks; however, the demand for better performing face masks by the general public still persists.

Our team has developed an easy-to-manufacture face mask design, called The HensNest, that provides the general public with a safe and reusable alternative to N95 masks. The HensNest consists of a simple plastic wireframe that can be quickly and cheaply manufactured. The wireframe can accept many filter types, all of which are intended to be commonly found in the home and disposable; and the plastic wireframe is dishwasher and disinfectant safe for repeated use.

The goal of this study is to evaluate the performance of The HensNest in filtering airborne particles of comparable size to those associated with transmission of COVID-19. Furthermore, we will directly compare the performance of The HensNest versus recommended at-home face masks, like sewn masks and bandanas, as well as rated N95 masks. This is an in-house study performed with a single test subject at our home institution, and our findings should thus be taken as preliminary.

METHODS

Quantitative respirator fit tests were performed using professionally rated and calibrated equipment (PortaCount Respirator Fit Tester 8038, TSI Incorporated). The OSHA Fast Fit Test Protocol was repeatedly performed on a single adult subject wearing multiple face masks. This protocol involves the subject performing multiple activities of daily living while wearing the mask, including normal breathing, bending over, turning head side-to-side, and jogging in place. The primary output from fit testing is the "Fit Factor," which is defined as the ratio of ambient particulate concentration to the concentration inside the mask, taken as an average across all activities prescribed by the test. A fit factor of 5 means that the face mask reduces particulate concentration by a factor of 5.

The respirator fit test equipment dispersed a known concentration of ultrafine salt particles (Particle Generator 8026 with Salt Tablets 80311, TSI Incorporated) into the ambient air and simultaneously quantified the particle concentration within the mask breathing volume via a sampling tube. Particle size ranged from 0.05 to 1.25 microns [1]; and coronavirus sizes (ca. 0.125 microns) are within this range [2]. Per OSHA protocol, calibration was performed immediately before mask testing (2702 particles per cm^3, maximum fit factor check 47379). For each mask fit test, a small puncture hole was made at a single location approximately 1 cm lateral to the nostrils and widened sequentially to accommodate the ¼" sampling tubing for the fit tester equipment (Figure 1). The puncture hole was sealed on the interior and exterior side of the mask using provided fittings.

Tests were performed on three different types of face masks that are commonly available and/or recommended for use by the general public (Figure 1): (1) disposable surgical masks with ear loops [3]; (2) sewn surgical mask (2-ply cotton blend) with ear loops [3,4]; and (3) bandana with ties constructed from t-shirt (1 ply, cotton blend)[4]. The HensNest lofted wireframe mask was also tested with several different replaceable filter materials, including: (1) HEPA filter material for a home furnace (Filtrete Ultra Allergen Air Filter, 3M Corp); (2) reusable grocery store bags (non-woven polypropylene, 1 ply); (3) paper coffee filter (2-ply); and (4) terrycloth cotton "tea towels" (1 ply) [3]. HEPA filter materials were tested in one and three-ply configurations. For benchmarking purposes, a rated N95 grade mask was also tested (Model 7130N95, North Safety Products).

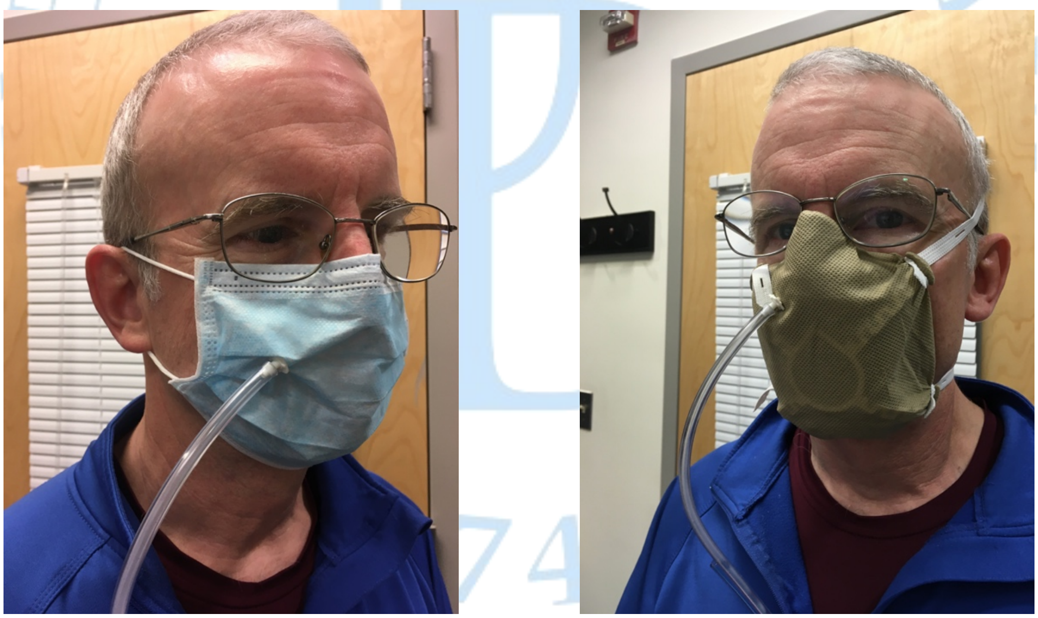

Figure 1: Experimental set-up for quantitative respirator fit testing of various face masks. Two different face masks are shown: (left) surgical mask; (right) HensNest with 1-ply reusable grocery bag (non-woven polypropylene) as filter material.

RESULTS

Fit test results for different mask types and filter materials are shown in Table 1. Surgical masks, sewn fabric masks, and bandanas all had a Fit Factor of 1, which essentially means that that they offer no particle filtration. HensNest masks outfitted with one ply of reusable grocery store bags or heavy cotton “tea towels” demonstrated Fit Factors of 3 to 4; and HensNest masks with one ply of HEPA furnace filter material registered a Fit Factor of 8. Increasing to triple ply of HEPA filter approximately tripled the Fit Factor to 23. The rated N95 mask demonstrated a Fit Factor of 83.

Table 1: Results of quantitative respirator fit testing on different mask types and filter materials.

Mask Type	Fit Factor
N95 Respirator	83
Surgical Mask	1
Sewn Mask	1
Bandana	1
HensNest (HEPA, 1 ply)	8
HensNest (HEPA, 3 ply)	23
HensNest (Grocery Bag)	4
HensNest (Coffee Filter)	1
HensNest (Tea Towel)	3

CONCLUSIONS

The results of this study suggest that the HensNest face mask design offers substantially greater protection as a respirator than face masks that are currently being suggested for use by the general public, including surgical masks, sewn fabric masks, and tied bandanas. Although its performance falls short of the protection offered by a rated N95 mask, the HensNest can reduce particulate counts in the size range of COVID-19 by a factor of three to eight, depending on the filter material that is used. Furnace filters are the most effective filter material to use with the HensNest, with each ply of the material approximately doubling the amount of filtration. Reusable grocery store bags and heavy cotton fabrics are also acceptable and actually offer substantially (3-4x) more protection than surgical or sewn masks. The relatively better performance of the HensNest design over other mask types for the general public may be attributed to the flexible wireframe achieving a tight seal around the face. Surgical and sewn masks, in particularly, demonstrated leakage at the interface between the mask and the face. The results of this study suggest that the HensNest offers greater protection as a respirator for the general public than surgical masks or other “do-it-yourself” face mask designs.

REFERENCES

[1] Reponen, T., Lee, S. A., Grinshpun, S. A., Johnson, E., & Mckay, R. (2011). Effect of fit testing on the protection offered by N95 filtering facepiece respirators against fine particles in a laboratory setting. *Annals of occupational hygiene*, *55*(3), 264-271.

[2] Fehr, A. R., & Perlman, S. (2015). Coronaviruses: an overview of their replication and pathogenesis. In *Coronaviruses* (pp. 1-23). Humana Press, New York, NY.

[3] Davies, A., Thompson, K. A., Giri, K., Kafatos, G., Walker, J., & Bennett, A. (2013). Testing the efficacy of homemade masks: would they protect in an influenza pandemic?. *Disaster medicine and public health preparedness*, *7*(4), 413-418.

[4] Mandoo, F., 2020. *Opinion | It'S Time To Make Your Own Face Mask*. [online] Nyti.ms. Available at: <https://nyti.ms/3bBlyw4> [Accessed 15 April 2020].