Flow In and Around Rapid Manufacture Face Masks

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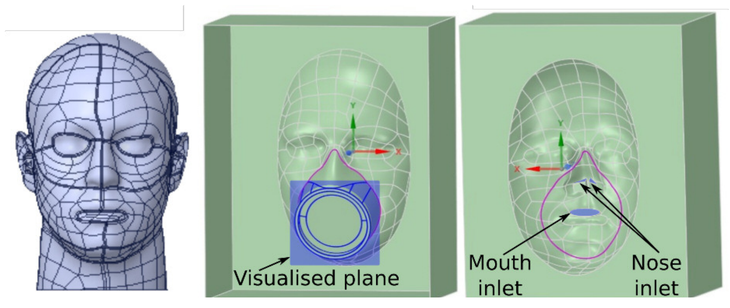
PROTECT
A COVID-19 National Core Study

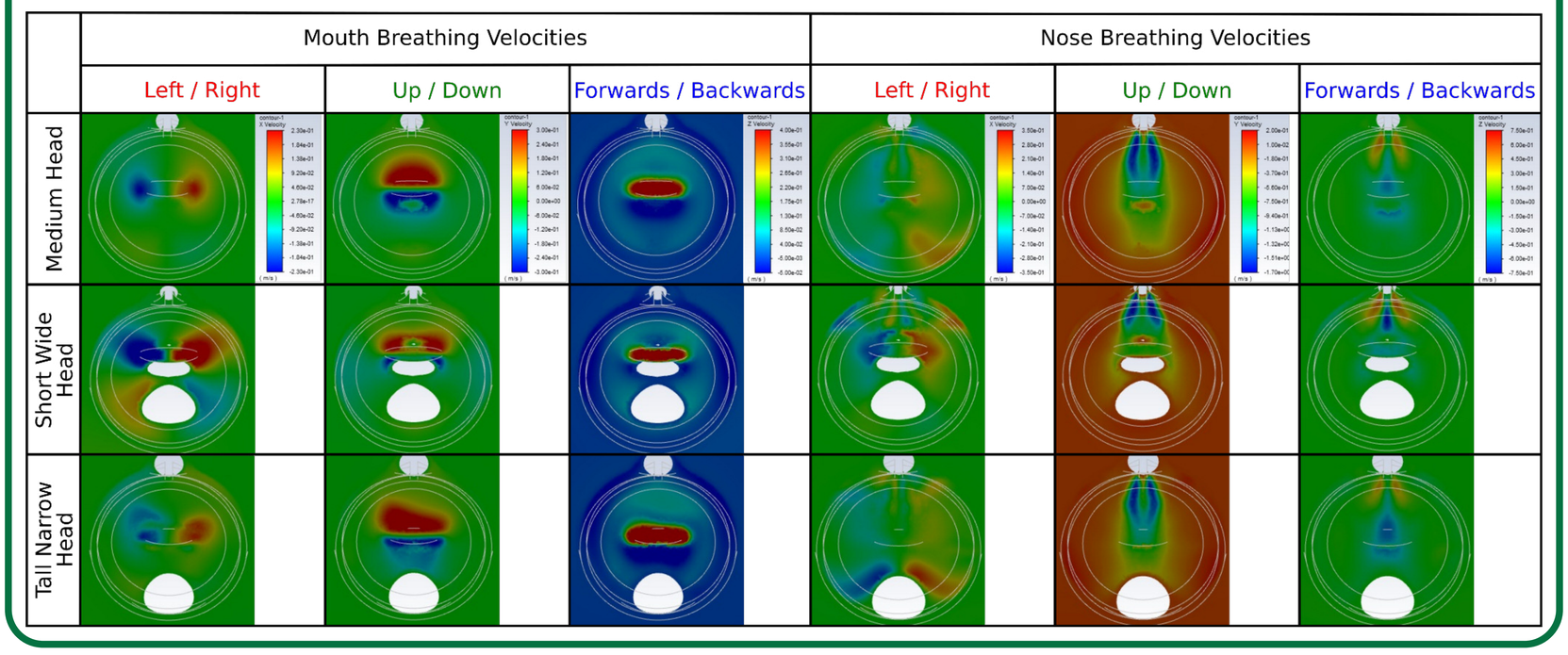
1. Introduction

Since the start of the COVID-19 pandemic, there has been increased interest in the effectiveness of different face coverings. However, face masks also have the potential to be used as a non-invasive diagnostic tool by sampling exhaled droplets using strips placed within masks [3, 2]. The best position for these strips remains an open question. Additionally, the ability to sample large and small exhaled droplets separately would give additional information on the origins of pathogens within the respiratory tract, and inform pathogen-specific strategies to prevent spread.

2. Computational Fluid Dynamics

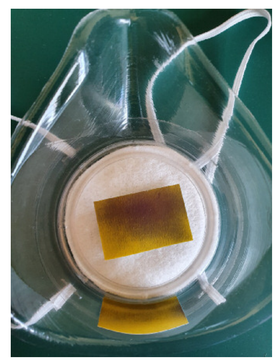
CFD simulations of mouth and nose exhalation (using a set of downloaded 3D heads) in a vacuum-formed mask (Mayku) show that the flow depends heavily on both breathing type and face shape, and a consistently acceptable position for sampling strips is difficult. Scan QR code for further plots and head details.

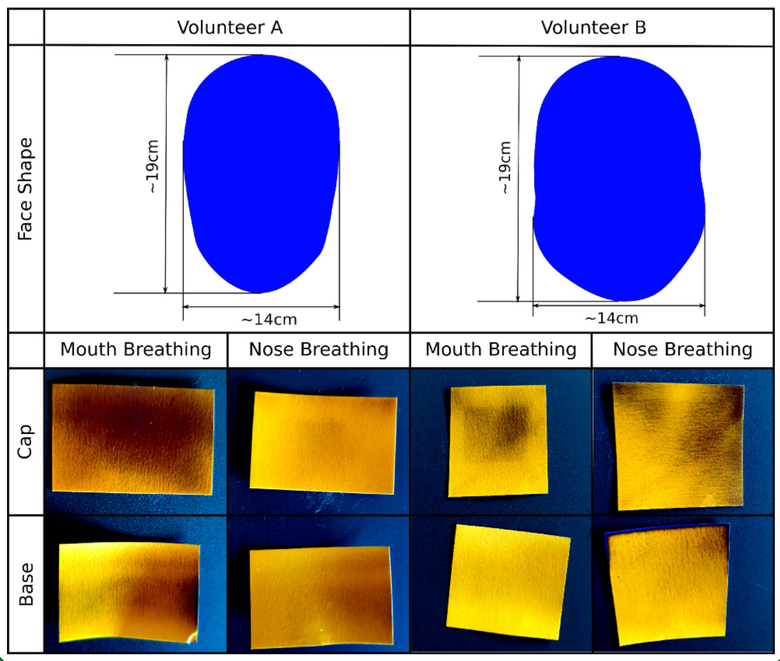




3. Mouth vs. Nose Breathing

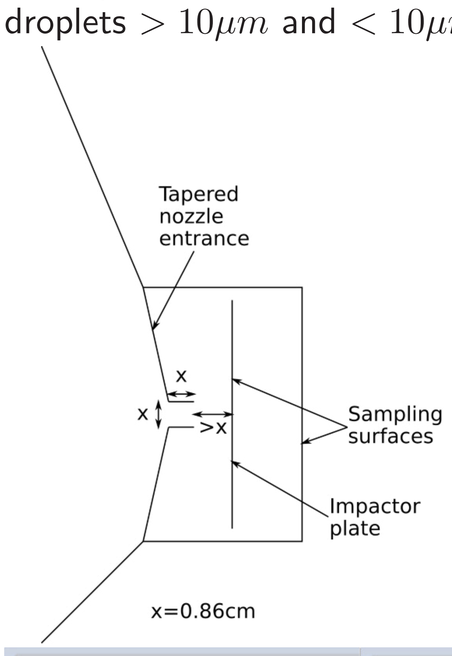
Water-sensitive paper strips placed within Mayku masks (and others) and worn by volunteers with differently shaped faces show that the droplet distribution changes with both face shape, and breathing type.

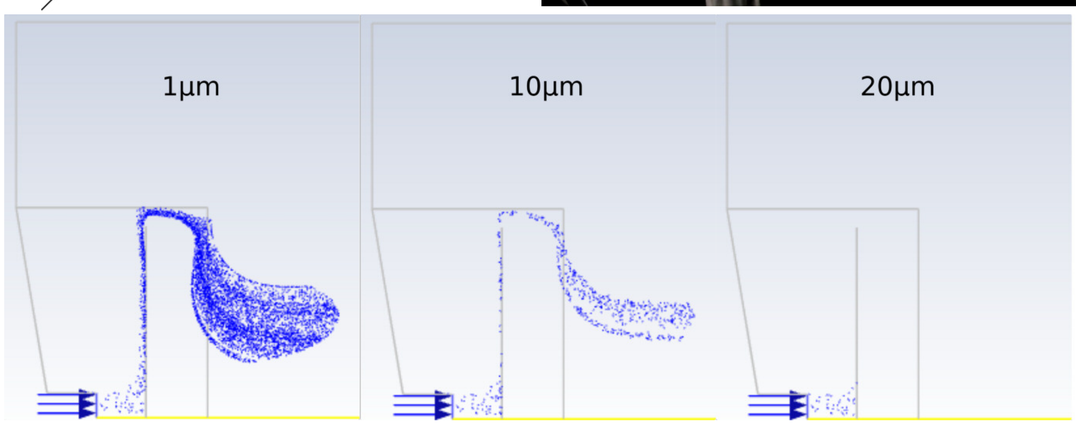


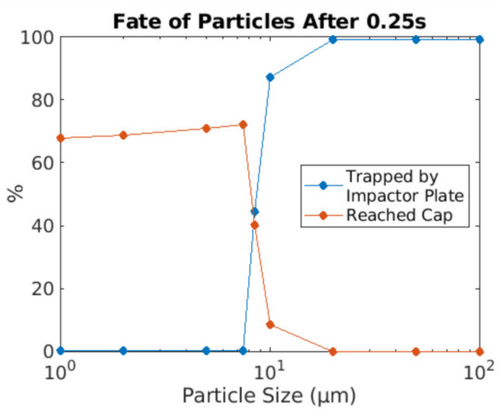


4. Sampling Mask Design

A mask specifically for sampling has been designed. Incorporating a nozzle makes flow between volunteers more comparable, and optimal strip positioning more straight forward. Including an impactor plate (based on an Andersen cascade sampler, following the design criteria of [1, 4]) should segregate droplets $> 10\mu m$ and $< 10\mu m$ for separate sampling (confirmed by axisymmetric CFD).

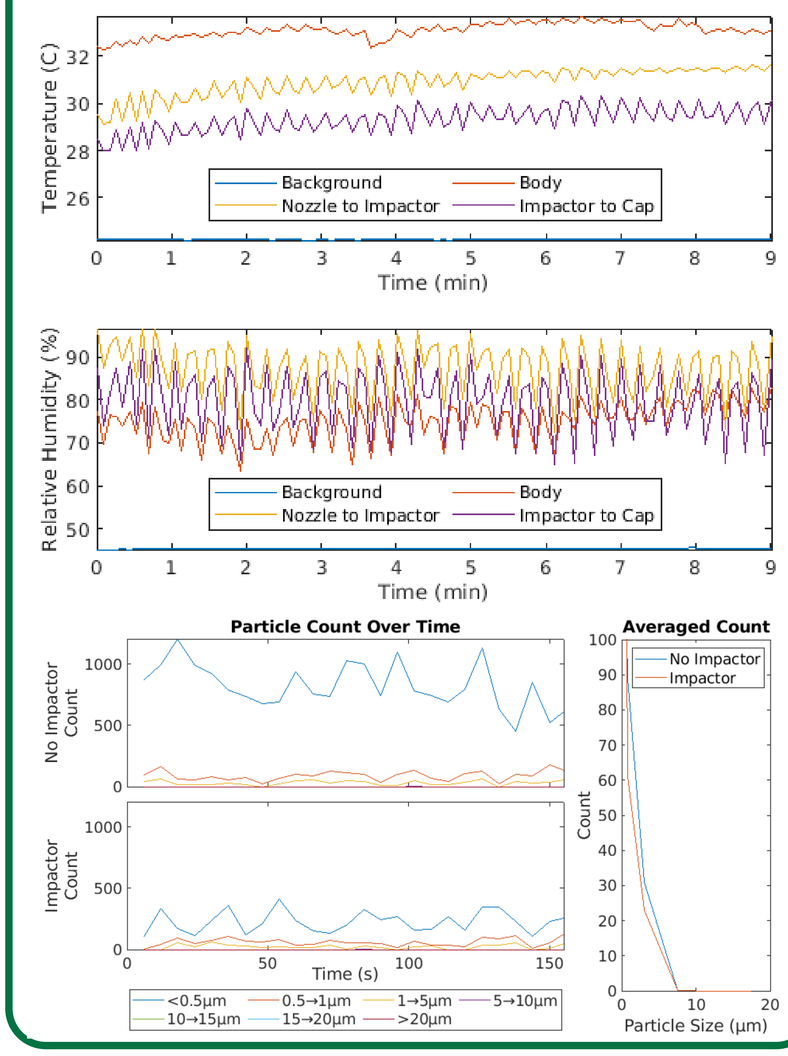






5. Preliminary Mask Testing

Preliminary testing of the sampling mask (using water-sensitive paper strips, a GRIMM OPC aerosol detector, and temperature and humidity sensors) has begun. Ongoing work will include experimental validation of the masks size segregation properties, and sampling strip tests.



6. Conclusions

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- In-mask flow depends on face shape and breathing type, making optimal positioning of sampling strips volunteer-specific.
- Testing has begun on a reproducible vacuum-formed mask designed specifically for sampling, with more consistent in-mask flow.
- This mask could allow size-segregated sampling, giving additional information on the spread of particular infections.
- Scan QR code for thermal camera videos of flow outside masks!

7. References

[1] Marple, V. A., and Willeke, K. Impactor design. *Atmospheric Environment (1967) 10*, 10 (1976), 891–896.

[2] Williams, C. M., Abdulwhhab, M., et al. Exhaled mycobacterium tuberculosis output and detection of subclinical disease by face-mask sampling: prospective observational studies. *The Lancet Infectious Diseases 20*, 5 (2020), 607–617.

[3] Williams, C. M., Cheah, E. S., et al. Face mask sampling for the detection of mycobacterium tuberculosis in expelled aerosols. *PloS one 9*, 8 (2014), e104921.

[4] Yao, M., and Mainelis, G. Investigation of cut-off sizes and collection efficiencies of portable microbial samplers. *Aerosol science and technology 40*, 8 (2006), 595–606.