

# Droplet Penetration Resistance Testing of CageMask Football Helmet Shield

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NANOSAFE, INC.

MARCH 3, 2020

# Testing Configurations



- Four configurations were tested for Outward Retention and Inward Penetration of cough-simulating droplets
  - Helmet only (Control, Riddell)
  - Visor (Under Armor)
  - CageMask
  - CageMask + Visor
- Three CageMask shields were received and tested in each relevant configuration
- Testing performed in Class 1000 cleanroom; particulate background  $<10 \text{ \#/cm}^3$
- Cough simulation generated via airbrush expulsion of DIN 53160 Artificial Saliva

# Experimental Setup: Outward Retention Testing

- Cough-simulating airbrush positioned at the expected location of the mouth within the helmet
- Headform with nasal sampling ports connected to Aerotrak 9306 Optical Particle Counter
- Distance between helmet facemask and sampling headform: 12"
- 5 measurements repeated for each configuration
- Each measurement characterized the average droplet concentration over a 10 second spray duration



# Experimental Setup: Inward Penetration Testing

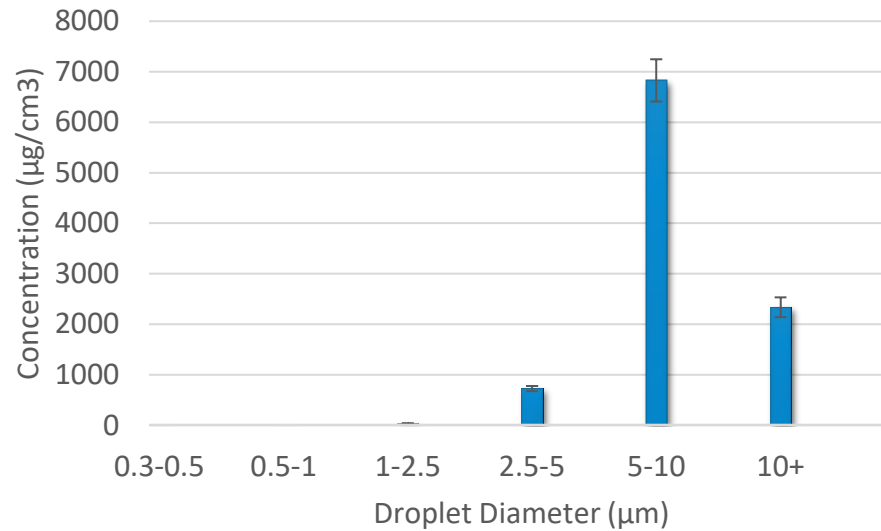
- Headform with nasal sampling ports connected to Aerotrak 9306 Optical Particle Counter fitted with helmet
- Cough-simulating airbrush positioned level with the center of the helmeted headform face
- Distance between airbrush and facemask of helmeted headform: 12"
- 5 measurements repeated for each configuration
- Each measurement characterized the average droplet concentration over a 10 second spray duration



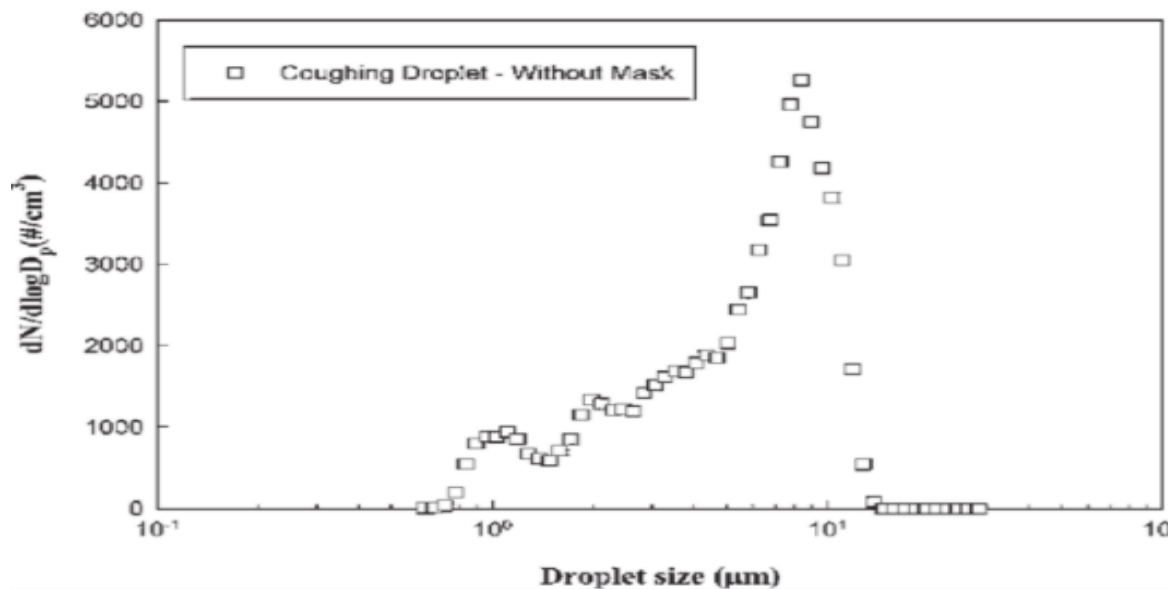
# Sprayed Droplet Characterization

- NanoSafe's cough-simulating airbrush closely mimics the droplet diameter distribution and air velocity of a human cough
  - Measured human cough exit velocities range from **1180-5500 ft/min<sup>1</sup>**
  - Measured NanoSafe airbrush exit velocity is **3410 +/- 35 ft/min**
  - Droplet diameter sizes are most concentrated at 5-10  $\mu\text{m}$  in both the NanoSafe-Generated spray and in measurements of a human cough<sup>2</sup>

NanoSafe-Generated Spray  
(Binned Measurements)



Human Cough Measurements  
(Yang et al)











<sup>1</sup> Wei, J. & Li, Y. *Human Cough as a Two-Stage Jet and Its Role in Particle Transport*. PloS one 12, e0169235-e0169235, doi:10.1371/journal.pone.0169235 (2017).

<sup>2</sup> Yang, S., Lee, G. W., Chen, C. M., Wu, C. C. & Yu, K. P. *The size and concentration of droplets generated by coughing in human subjects*. Journal of aerosol medicine : the official journal of the International Society for Aerosols in Medicine 20, 484-494, doi:10.1089/jam.2007.0610 (2007).

# Testing Results

## Results: Outward Retention Inward Protection

|  |  |  |  |  |  |  |  |  |  |
|--|---|---|---|---|--|---|---|--|---|
|  | Helmet Only   | Visor   | CageMask  | CageMask + Visor  |  | Helmet Only   | Visor   | CageMask   | CageMask + Visor  |
| 0.3-1 $\mu\text{m}$ Reduction (by #)   | 0% (Control)  | -11.9% +/- 4.4%   | 95.4% +/- 1.8%  | 95.4% +/- 0.9%  |  | 0% (Control)  | 30.2% +/- 10.4%   | 29.7% +/- 9.4%   | 68.6% +/- 3.5%  |
| 1-25 $\mu\text{m}$ Reduction (by mass) | 0% (Control)  | 22.6% +/- 19.1%   | 99.6% +/- 0.1%  | 99.9% +/- 0.0%  |  | 0% (Control)  | 27.9% +/- 12.0%   | 72.9% +/- 4.4%   | 87.8% +/- 2.3%  |

- % Reduction calculated as  $1 - \frac{\text{Measured Concentration}}{\text{Control Concentration}}$
- Particles sized 0.3-1  $\mu\text{m}$  measured as  $\#/m^3$
- Particles sized 1-25  $\mu\text{m}$  measured as  $\mu\text{g}/m^3$
- Standard error reported
  - 5 measurements per sample
  - Measurements across 3 CageMask samples agglomerated (15 total measurements)

- The CageMask provided greater than 95% retention of total measured particulates (>99.6% retention of droplets sized 1-25 $\mu\text{m}$ )
- A visor provided little retention of expelled particulates; in fact, a slight increase in expelled fine particulates was measured over control concentrations when a visor was fitted to the helmet
- All shields tested provide less Inward Protection compared to Outward Retention (i.e. shields protect other players to greater effect than the user)
- While use of both CageMask + Visor provides greatest Inward Protection to the player, Outward Retention of expelled droplets is not significantly improved when a visor is added to the CageMask alone

# Discussion

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- The CageMask provides significant retention of cough-like droplets that may be expelled by a player (>95.5% of droplets sized 0.3-1  $\mu\text{m}$  and >99.6% of droplets sized 1-25  $\mu\text{m}$ )
- Use of a dual visor configuration affords greatest protection against inward penetration of droplets\*
- Use of a dual visor configuration provides negligible additional retention of droplets from wearer over CageMask alone\*

\*At the head-on angles measured in this session. Evaluation of efficacy at different orientations that may be experienced during sport activities requires further study.

# Conclusions

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- **CageMask provides:**



- **Protection to other players**

- Blockage of up to 99.6% of droplets expelled by wearer\*



- **Protection to wearer**

- Blockage of up to 72% of droplets traveling toward the wearer\*



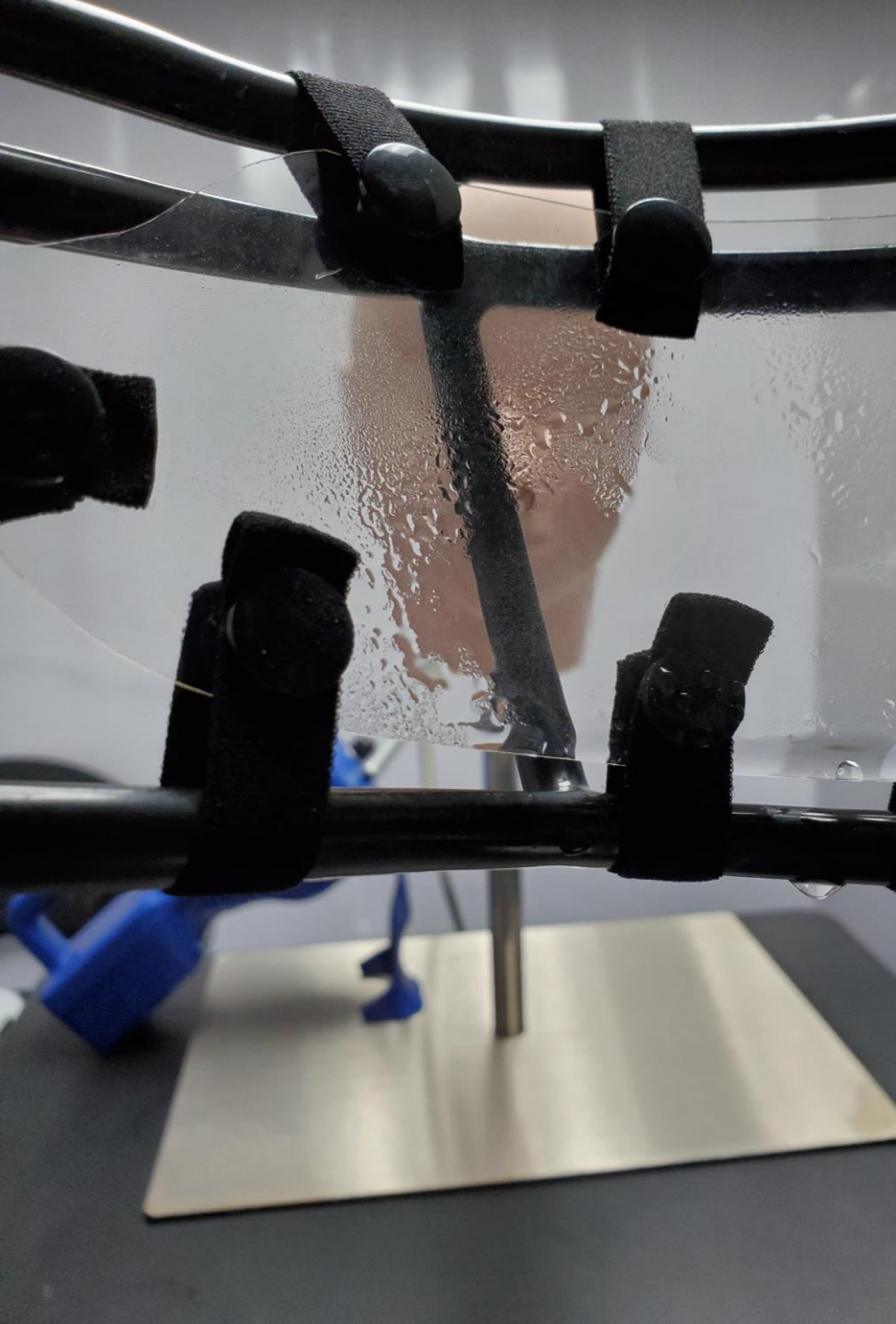
- With upper visor, blockage of up to 87% of droplets traveling toward the wearer\*

- Use of a dual CageMask + Visor configuration affords greatest protection against inward penetration of droplets\*\*
- Use of a dual visor configuration provides negligible additional protection for other players over CageMask alone\*\*

\*Droplet sizes 1-25  $\mu\text{m}$  sprayed horizontally, measured at a lateral distance of 12" from the wearer

\*\*At the head-on angles measured in this session. Evaluation of efficacy at different orientations that may be experienced during sport activities requires further study.





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Further questions welcome. Contact:

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