Does Wearing a Hat Reduce Exposures? An Examination of Particle Aspiration

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Background

Previous computational fluid dynamics (CFD) studies identified changes in human aspiration due to protrusions of facial features. In low velocity wind speeds typical of occupational settings (0.1 – 0.4 m s^{-1}) gravitational settling causes large particles (≥ 68 μm) to have predominantly downward vertical trajectories. It is hypothesized the brim of a hat would also cause a reduction in aspiration of large particles.

Objective

The objective of this work was to quantify the reduction in human aspiration efficiency for an inhaling humanoid model wearing hats with different brim lengths in low velocity wind speeds.

Methods

Generated humanoid geometry with realistic facial features and three different hats for facing-the-wind orientation

- Baseball cap (long brim)
- Hardhat (short brim)
- No hat

Ran CFD model and solved fluid flow

- Fluent 12.0 and 13.1
- Facing-the-wind orientation
- Freestream velocities: 0.1, 0.2, and 0.4 m s^{-1}
- Constant mouth-breathing inhalation: 1.81, 4.33, and 12.11 m s^{-1} to represent at-rest, moderate, and heavy breathing, respectively
- Standard k-epsilon turbulence model, 2nd order upwinding
- Assess mesh independence and iterative convergence

Simulated laminar particle trajectories

- Determined critical areas defining where particles would be inhaled from the freestream

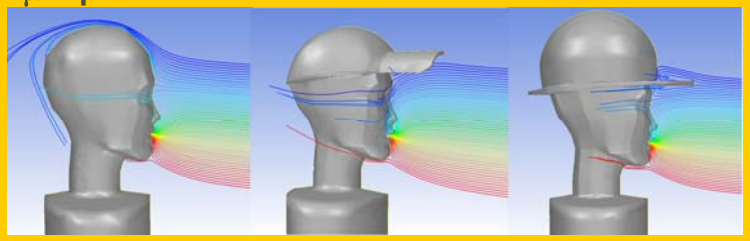
Compared aspiration efficiency estimates between hat models and no-hat model

- Computed differences between hat models and no-hat model
- Computed one-tailed student's t-test, paired by velocity condition and particle size

Results

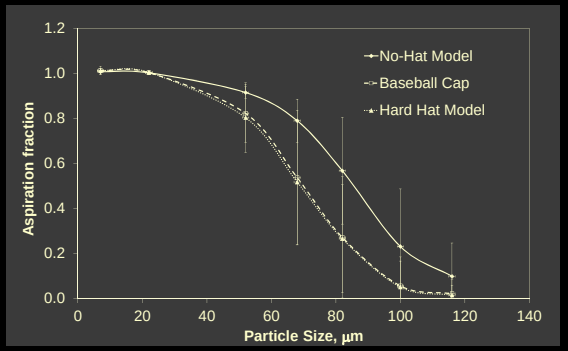
Particle trajectories for 0.2 m s^{-1} freestream velocity, heavy breathing (12.11 m s^{-1})

7 μm particles



82 μm particles

Difference in Mean Aspiration Efficiency Estimates (fraction) between Hat Models



Key Findings

- Hats with a brim resulted in significantly lower aspiration ($p<0.001$) when compared to the no-hat model.
- Hats substantially reduced aspiration on average 40% for particles ≥68 μm.
- Hats resulted in negligible aspiration reductions for particles <68 μm (0-6%).
- Negligible differences were seen between two hat types.
- The presence of the hats forced air to converge toward the mouth causing a slight increase in aspiration for particles <22 μm.

Conclusions

Hats can be used to reduce exposure to large particles.

Caution should be used when small particles are present, as hats caused an increase in aspiration for ≤ 22 μm.

Future Research

Future research should account for thermal effects from the body.

The presence of a brim could prevent the thermal plume from body heat rising away from the body, increasing exposure to gaseous contaminants and small particles.

Additional research needs to be conducted to investigate orientation-averaged effects.

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