

Investigation of Particle Bounce on Human Aspiration Efficiency: A Computational Fluid Dynamics (CFD) Study

Kimberly Anderson, MS, T. Renée Anthony, PhD

Department of Occupational and Environmental Health, The College of Public Health, The University of Iowa

Background

Computational fluid dynamics (CFD) was used to examine the effect of particle bounce on human aspiration efficiency estimates. Particle bounce during air monitoring can lead to oversampling, biasing exposure assessments. However, the effect on human aspiration has not been investigated.

Objective

The objective of this work was to quantify the effect of bounce in human aspiration efficiency simulations.

Methods

Generated three humanoid geometries with realistic facial features, facing the wind

- Small Nose, Small Lip
- Large Nose, Large Lip
- Small Nose, Large Lip

Ran CFD model and solved fluid flow

- Fluent, 12.1 (Ansys, Inc.)
- Freestream velocities of 0.2 and 0.4 m s⁻¹
- Mouth breathing velocities of 1.81 and 12.11 m s⁻¹ to represent at-rest breathing and heavy breathing rates, respectively
- Standard κ -epsilon turbulence models, 2nd order upwinding
- Assessed mesh independence, iterative tolerance

Assigned coefficient of restitution (CoR) to facial surfaces

- 0, 0.5, 0.8, 1.0

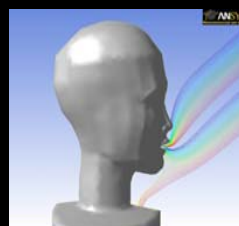
Simulated laminar particle transport

- Determined the upstream area where particles would be inhaled (critical area)
- Computed aspiration efficiency

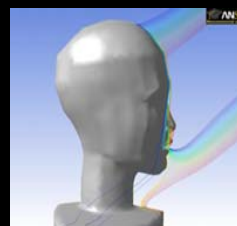
Compared aspiration efficiency estimates between CoR

- Computed differences in aspiration efficiency between no-bounce and 100% bounce
- Computed Tukey's method of multiple comparisons to identify the accuracy needed in model

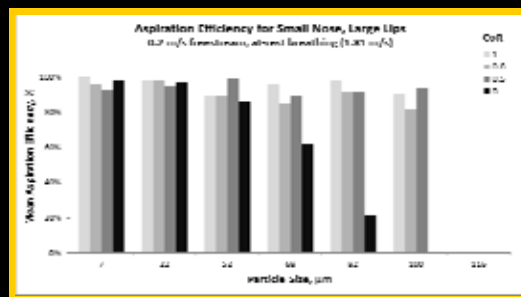
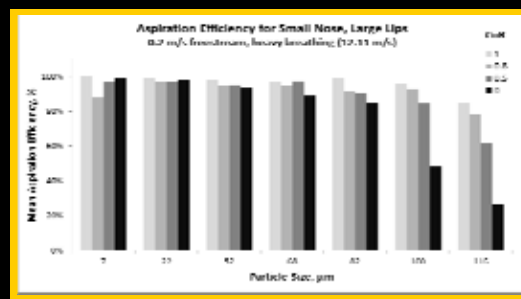
0 CoR



1.0 CoR



68 μ m particles, released upstream in the critical area. Particles below the upper blue stream and above the lower red stream are aspirated, while particles outside are not.



Aspiration for the 116 mm particles was zero for at-rest breathing for all CoRs, resulting in no differences

Particles ≤ 52 mm had $<5\%$ differences, particles >52 mm on average had larger differences (37%)

Results

Table 1: Tukey Method for Multiple Comparisons

| CoR | CoR | | | |
|-----|-----|--------|--------|--------|
| | 0 | 0.5 | 0.8 | 1 |
| 0 | - | <0.001 | <0.001 | <0.001 |
| 0.5 | - | - | 0.9982 | 0.7686 |
| 0.8 | - | - | - | 0.8561 |

Significant differences between the no-bounce and 100% bounce conditions were found ($p = <0.0001$ to 0.0016)

No significant differences between 0.5 and 0.8, 0.5 and 1.0 or 0.8 and 1.0 ($p = 0.52$ to 0.998)

Overall, differences between the no-bounce and 100% bounce ranged from -8 to 105%

Aspiration efficiency estimates between facial features were not significant ($p = 0.2$ to 0.8)

Conclusions

Facing forward, secondary aspiration from particles bouncing on the face are *less important* for *small* particles, but become *more important* as particle size *increases* above 52 μ m.

If experimental studies do not quantify bounce parameters, between-study comparisons will be difficult.

Future Research

Further research is necessary to obtain a realistic value of CoR for human skin.

Additional simulations are needed to examine these differences across the full range of orientations to fully compare to the Inhalable Particulate Mass Criterion (IPM).

Acknowledgments

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