Computational Fluid Dynamic Study Investigating Airflow into the Inhaling Mouth: Effects of Torso Geometry Simplifications

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Background

Computational fluid dynamics has been used to examine particle inhalability in low velocity freestreams. Realistic faces but simplified human torsos were used. When compared to wind tunnel velocity studies, the truncated models were found to underestimate the air's upward velocity near the human, which may affect particle aspiration estimates.

Objectives

Determine the effects of torso geometry on airflow into the inhaling mouth using three torso geometries

Methods

Three geometries were created:

- Four sets of mesh densities were created for each geometry
- Node spacing decreasing by a factor of 1.2 between sequential meshes

Standard k-epsilon turbulence models were used

Four combinations of velocity were assessed

Vertical velocities were compared

- The truncated torso velocity was used as the baseline
- Agreement was assessed using linear regression

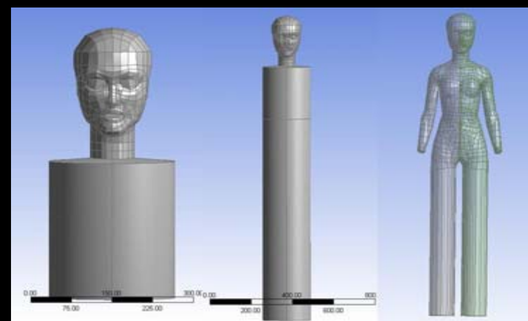
Details of Mesh Dimensions for Coarse (M1), Mid (M2) and Fine (M3) Grid Densities for Each Torso Geometry

Torso Type		Mesh Density M1	M2	M3
Truncated Cylinder	Nodes	291,532	621,272	1,113,039
	Elements	1,471,892	3,303,299	6,000,132
Non-truncated Cylinder	Nodes	172,028	316,395	582,200
	Elements	841,508	1,634,149	3,059,413
Anthropometric realistic humanoid body	Nodes	732,788	1,291,572	2,308,915
	Elements	3,948,179	7,018,339	12,830,832

The coarsest meshes have between 172,000 (truncated) and 733,000 (full-human) nodes, and the most refined meshes have between 1,113,000 (truncated) and 2,309,000 (full-human) nodes

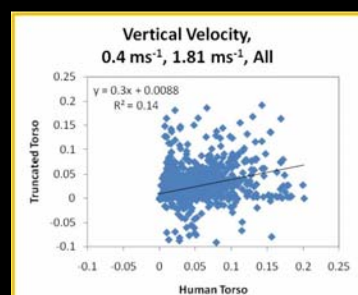
Geometries

Truncated Cylindrical Torso | Non-truncated Cylindrical Torso | Humanoid Body

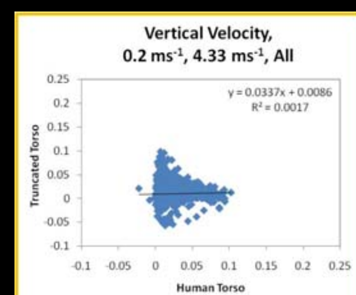


The three geometries used for airflow investigation. The truncated cylinder is truncated at approximately waist height. The non-truncated cylindrical torso was matched to the 50th percentile female height. The anthropometrically realistic torso was matched to the 50th percentile female dimensions.

Results



Best Fit Linear Regression Model of Freestream Velocity and Breathing Velocity Conditions

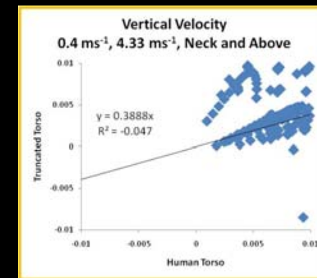


Worst Fit Linear Regression Model of Freestream Velocity and Breathing Velocity Conditions

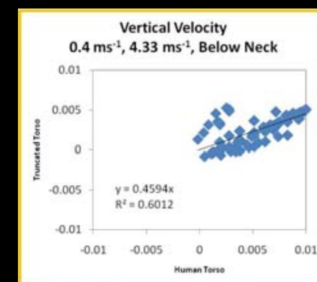
Linear Regression Models

Test Velocity ($m\ s^{-1}$) Freestream	Breathing	Full/Truncated Slope	R^2	Human/Full Slope	R^2	Human/Truncated Slope	R^2
0.2	1.81	0.86	0.66	0.56	0.43	-0.04	0.00
0.2	4.33	0.18	0.24	-0.17	0.04	0.03	0.00
0.4	1.82	0.18	0.03	0.13	0.02	0.30	0.14
0.4	4.33	0.76	0.53	0.71	0.39	0.26	0.10

The linear regression models show that there is a lack of correlation between the different torso geometries, indicating that vertical velocity is affected by the geometry used



The velocity for the neck and above has worse agreement between geometries. This may affect aspiration efficiency estimations



The velocity data for below the neck has better agreement between geometries

Conclusions

- Torso geometry affected vertical air velocity
- Velocity differences were greatest in the neck and head region
- Aspiration efficiencies may be affected by torso geometry

Future Research

- Complete convergence assessment
- Conduct particle aspiration studies to evaluate aspiration efficiencies
- Quantify the errors introduced by using a simplified geometry
- Recommend the required level of detail to adequately represent a human form in CFD studies of aspiration efficiency

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