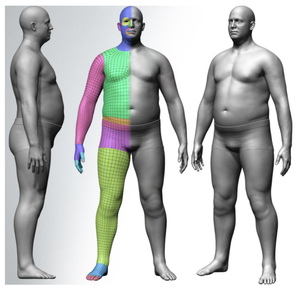
Influence of obesity on biomechanics models and simulations

K. Marchetta, J. Hausselle, A. Azoug
MS²M Lab – BAMM Lab – Mechanical and Aerospace Engineering – Oklahoma State University

Background

- Today, 37.7% of the United States populations suffers from obesity and is prone to adult-onset diabetes [1]
- Biomechanical simulations of motions are commonly developed using a generic model of the human body scaled according to the weight and height
  - As the BMI of a subject increases, we hypothesize that the weight distributions of these models become less accurate



[2]

- Mobile 3D body scanner is beneficial for conducting scans anywhere. It is also an affordable alternative, for this is the begining of the BAMM Lab's implementation of 3D scanning subjects

Objective

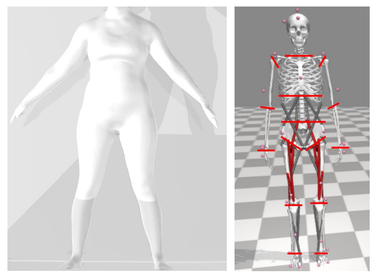
Scan human subjects with various morphologies to quantify the Body Mass Index above which a subject-specific musculoskeletal model is necessary for the accurate evaluation of body dynamics.

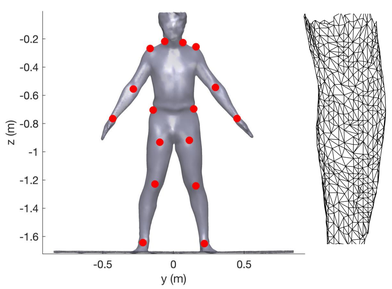
Method

- IRB approved study
- 3D scan human subjects with various morphologies
- Table created to track subject pool
- Goal = obtain 10 male and female subjects in each BMI categories: <24.9, 25-29.9, 30-34.9, >35 kg/m²

Gender	BMI	Subject Count
	<24.9	2
	25-29.9	1
	30-34.9	1
Males	>35	
	<24.9	11
	25-29.9	4
	30-34.9	
Females	>35	

[3]



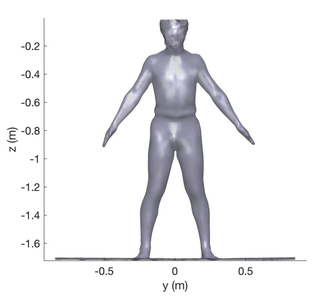


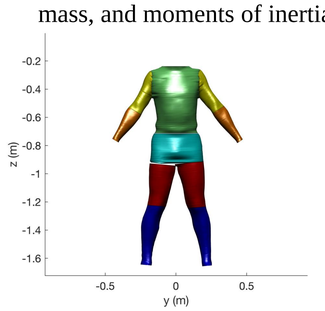
- Process the 3D scans as .obj files in MATLAB:
  - Define 16 markers: left and right ankle, knee, hip, waist, shoulder, elbow, wrist, neck.
  - Divide each body segment based off the 16-segment model that is generated in OpenSim
  - Calculate anthropometric measurements, volume, center of mass (CoM), and moments of inertia of each body segment
- Define a subject-specific OpenSim model:
  - Scale each bone
  - For each segment: input subject's specific mass, CoM location, and moments of inertia
- Simulate dynamic motions in OpenSim using subject-specific inertial parameters
- Compare with simulations using scaled inertial parameters

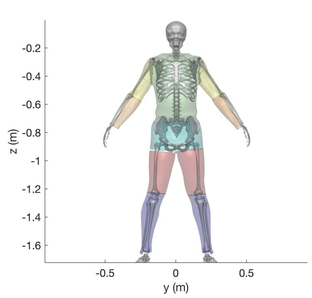
Results

- Markers are placed manually on the image of the scan. To compensate for uncertainty, each subject is scanned 3 times, and each scan is processed 3 times.
- Body geometry is "cut" at markers position, remeshed, and closed to allow for moment of inertia computation.
- Each segment is a closed meshed geometry ⟹ can be numerically manipulated
- Scaled musculoskeletal model developed in OpenSim shows good agreement with 3D scanned body geometry.

Image of the 3D scan Subject male, 20 y.o., 73 kg → 3D scan processed in Matlab → Body divided in segments, each with its mass, center of mass, and moments of inertia → OpenSim model scaled and fitted to the scan position







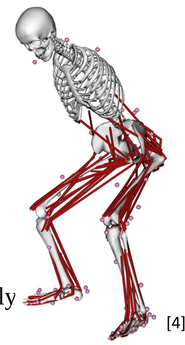
Conclusions and Future Work

Conclusions:
- Scans will continue to be processed by segments into closed volumes
- An OpenSim model has been created to be fitted to the scans
- MATLAB to OpenSim communication is automatic for easier data processing

Difficulties:
- Scans can have some defects depending on how still the subject can remain – this creates difficulties during the MATLAB processing.
- Finding diverse morphologies from our subject pool was limited – likely due to apprehension for those in higher BMI categories
- The IRB process can take longer than anticipated
- Scaling and representing the model in 3 dimensions was more complex than expected

Positive aspects:
- The scanner has proven a reliable technology
- Optimistic about future data processing as the codes have been refined

Further Work:
- Keep scanning large population of subjects
- Target subject pool with a higher BMI category
- Set up an inverse kinematic simulation in OpenSim
- Determine the influence of morphology on body dynamics
- Compare to the commonly-used scaled generic model



[4]

References

[1] Overweight and Obesity Statistics Overweight & Obesity Statistics | NIDDK (nih.gov)
[2] Overweight Male Basemesh 3D Model https://www.cgtrader.com/3d-models/character/woman/overweight-male-basemesh
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[4] Musculoskeletal model https://www.researchgate.net/figure/Musculoskeletal-model-OpenSim-SimTK-33-Stanford-USA-9-based-on-the-common_fig1_327972824

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