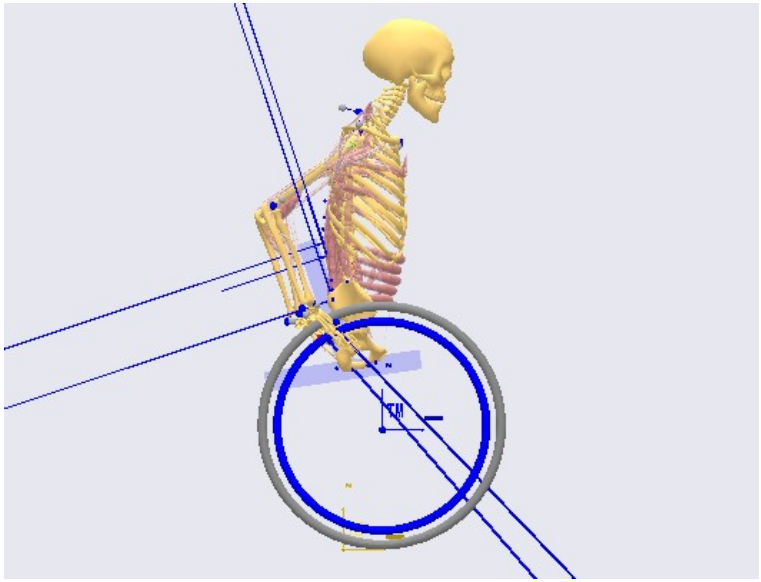
Adjusting the Axle Placement in Wheelchair Users to Minimize Shoulder Joint Forces

Sarah Sullivan-Dubowsky



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Sarah Sullivan-Dubowsky
(Presenter)

Søren Tørholm
(Panelist)

Arne Kiis
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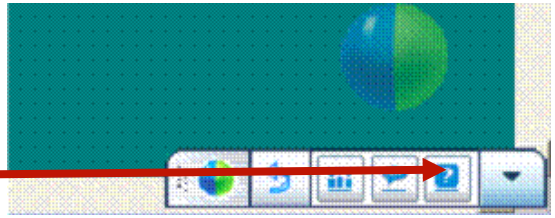

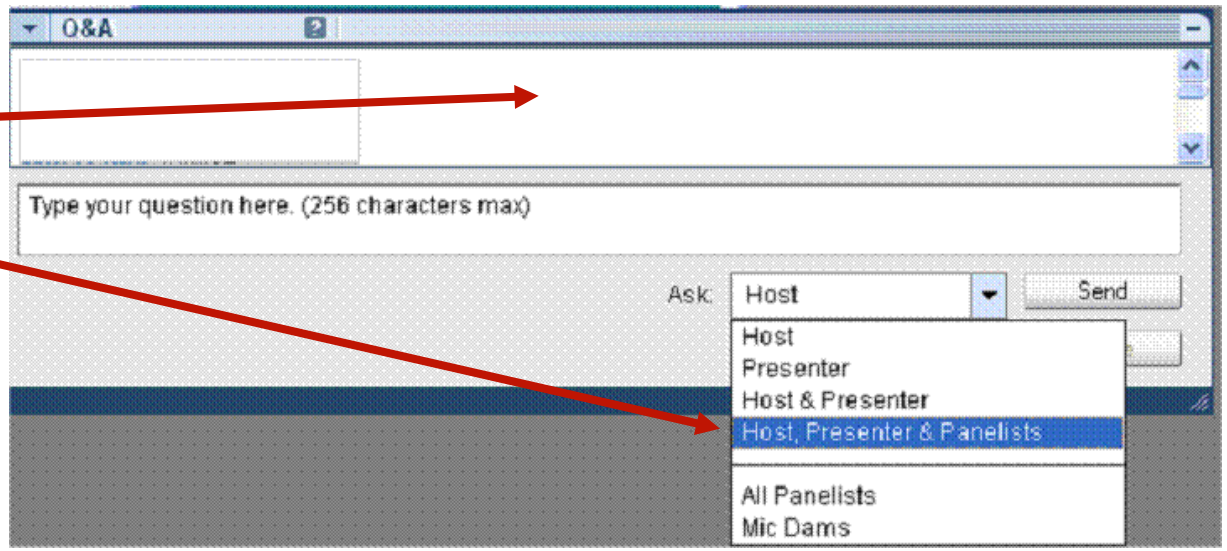

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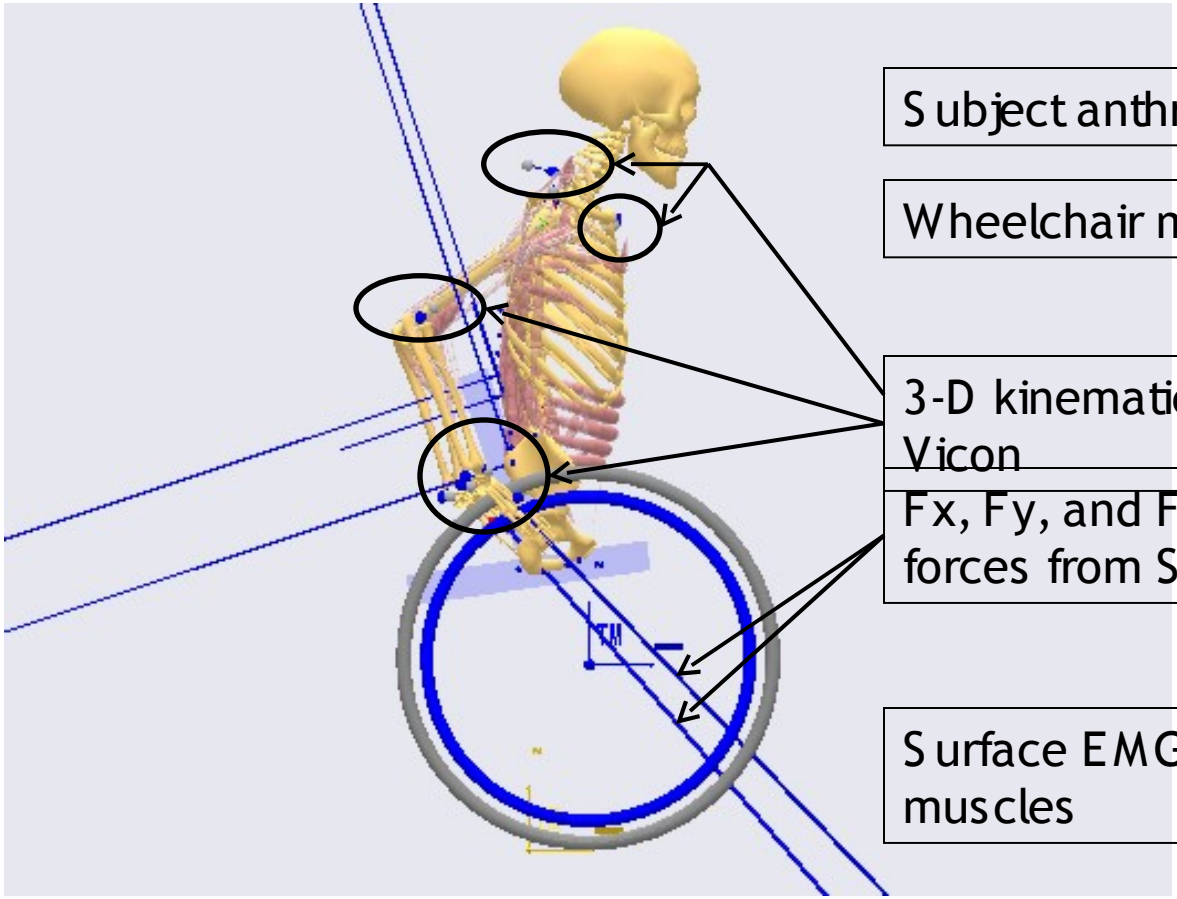
Overall Goal

- Create a patient-specific model of wheelchair propulsion for investigating axle placement to minimize shoulder joint forces.
- Potential for use in prescribing wheelchairs
- Potential for use as an intervention

Overview

- Review of data collection and analysis
- Construction and validation of model
  - EMG activity comparisons between computational and experimental results
  - Kinetics comparisons when model is driven by torque
- Parametric study investigating the effect of axle placement on shoulder joint forces

Data Acquisition



Subject anthropometrics

Wheelchair measurements

3-D kinematics from Vicon

Fx, Fy, and Fz propulsion forces from SMART^{Wheel}'s

Surface EMG from 12-muscles

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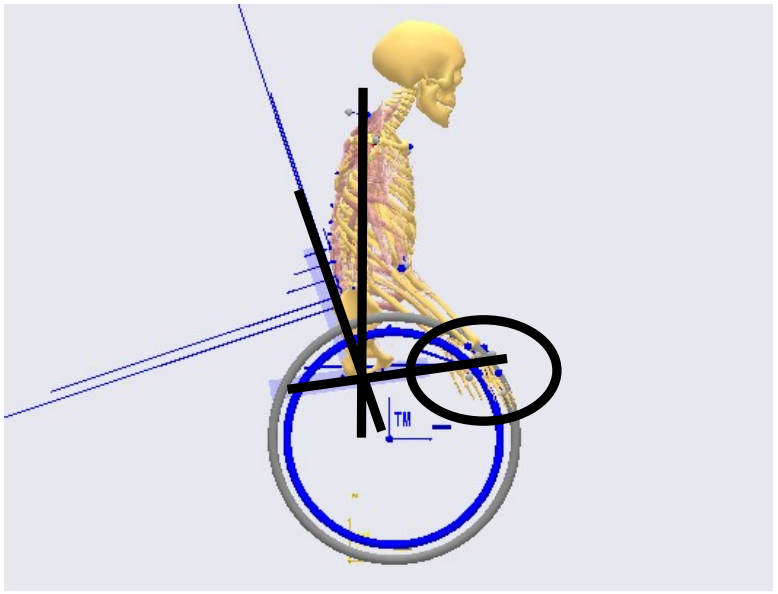
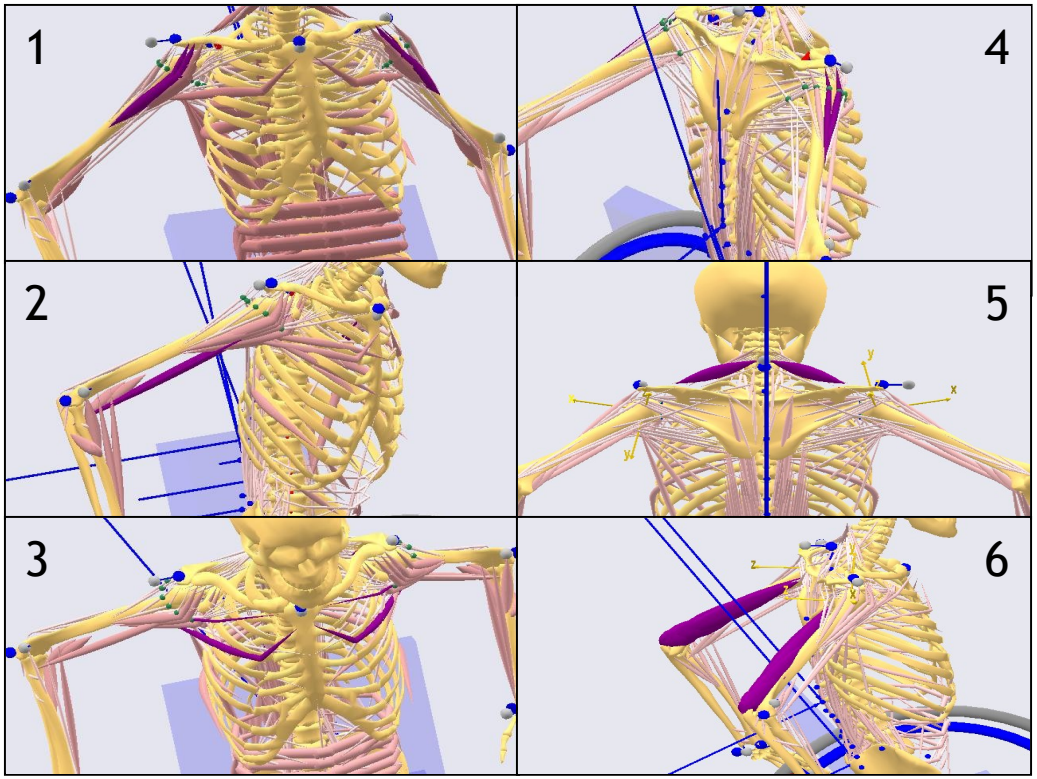
Model

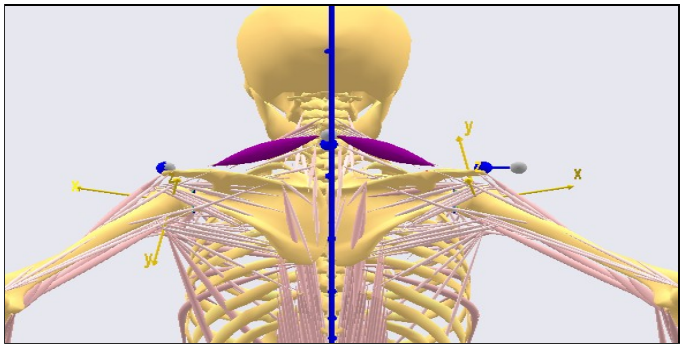


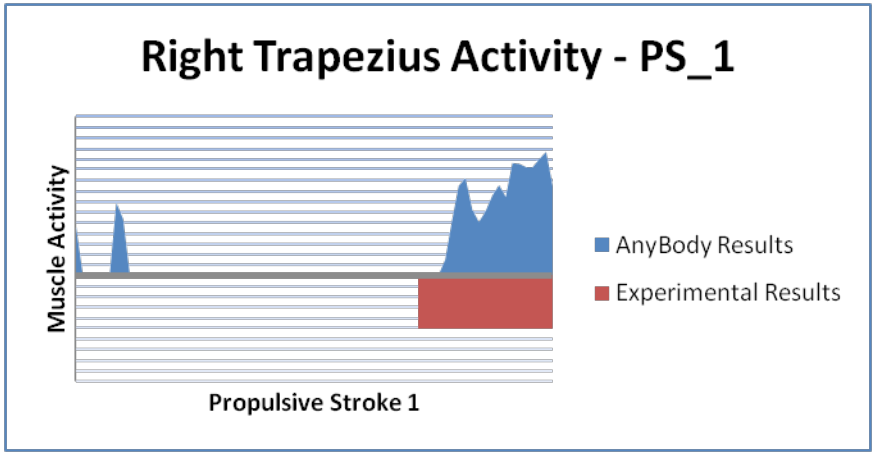
Validation (I) – EMG Comparison

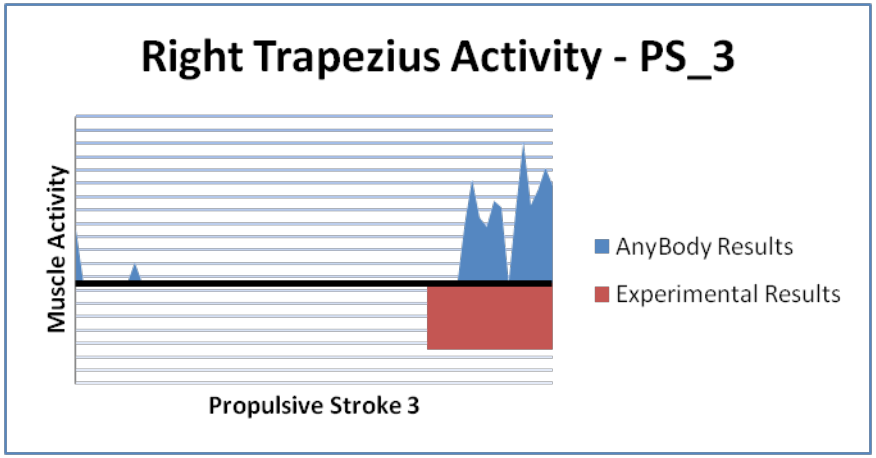


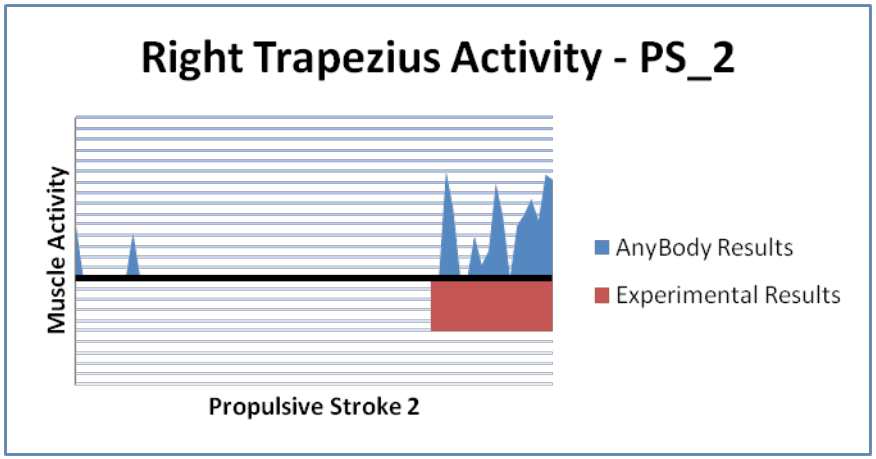
1. Anterior deltoid; 2. Biceps; 3. Pectoralis major; 4. Posterior deltoid; 5. Trapezius; 6. Triceps

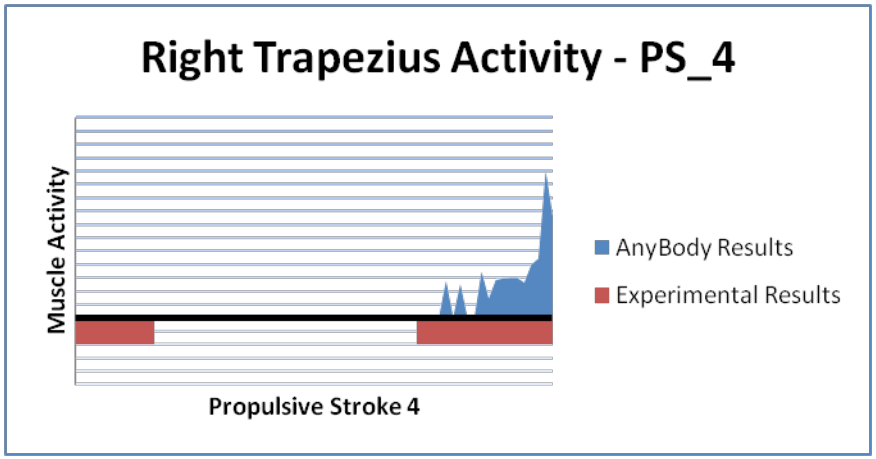
- Muscles in the model are represented as multiple fibers
- Compare each computational fiber's activity with experimental activity
- Highlighted (purple) fibers correspond to participant EMG



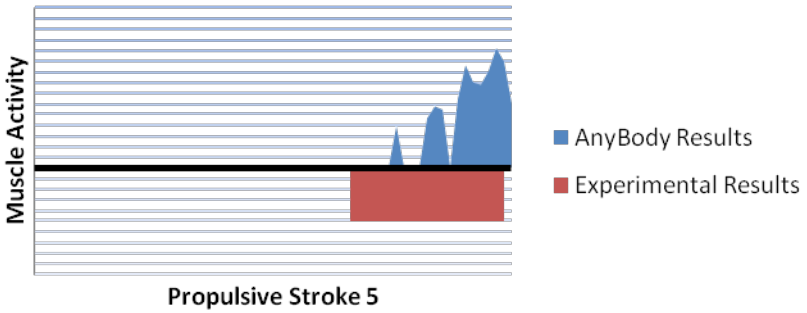

Right Trapezius Activity - PS_1
Muscle Activity
AnyBody Results
Experimental Results
Propulsive Stroke 1


Right Trapezius Activity - PS_3
Muscle Activity
AnyBody Results
Experimental Results
Propulsive Stroke 3

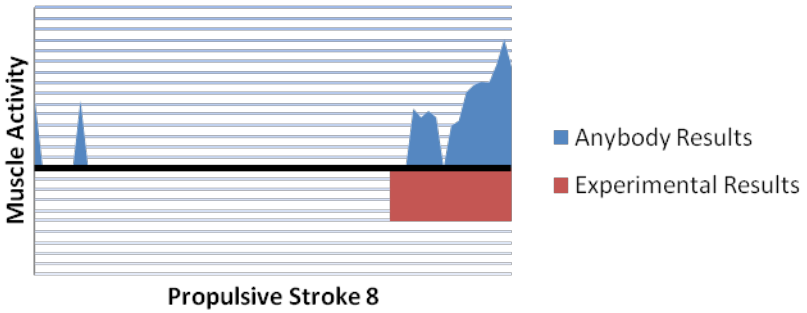

Right Trapezius Activity - PS_2
Muscle Activity
AnyBody Results
Experimental Results
Propulsive Stroke 2


Right Trapezius Activity - PS_4
Muscle Activity
AnyBody Results
Experimental Results
Propulsive Stroke 4

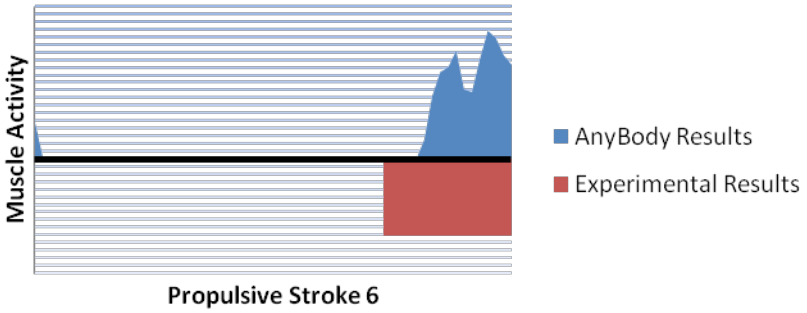
Right Trapezius Activity - PS_5



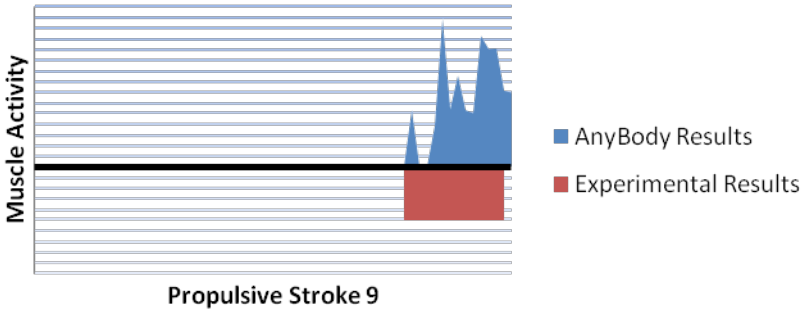
Right Trapezius Activity - PS_8



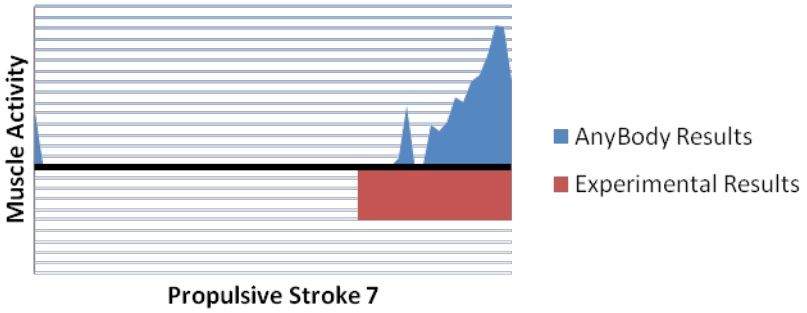
Right Trapezius Activity - PS_6



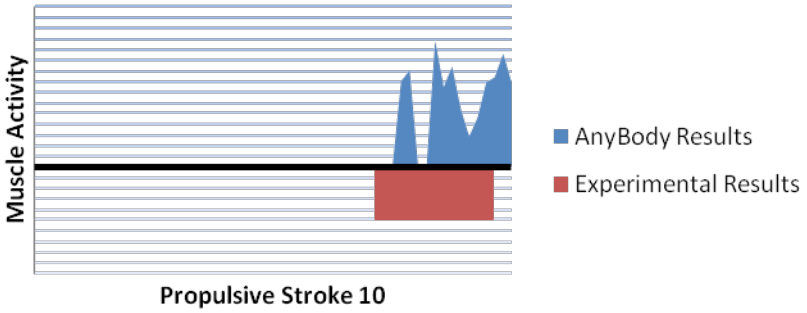
Right Trapezius Activity - PS_9



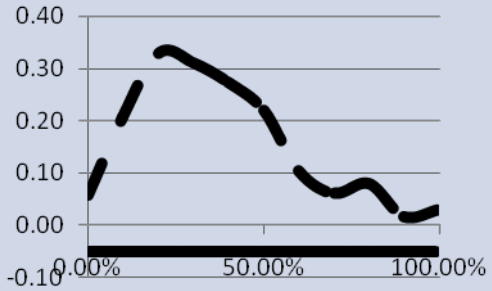
Right Trapezius Activity - PS_7



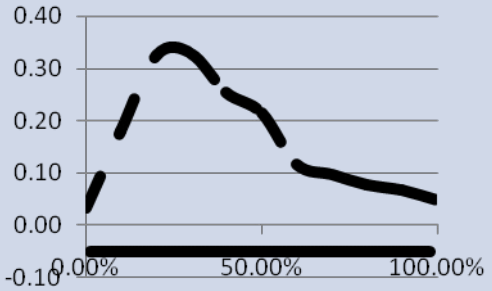
Right Trapezius Activity - PS_10



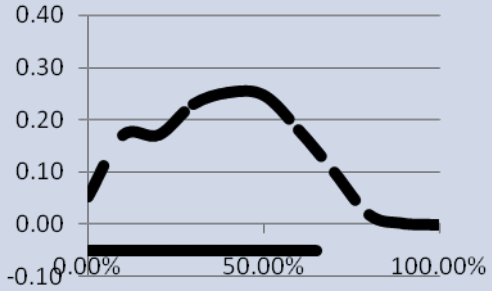
Left Anterior Deltoid



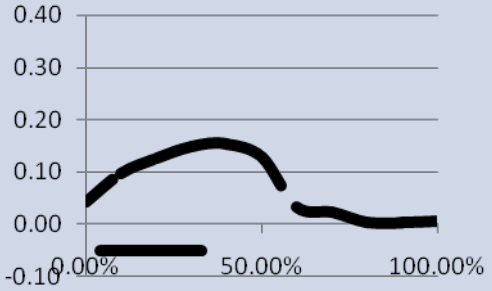
Right Anterior Deltoid



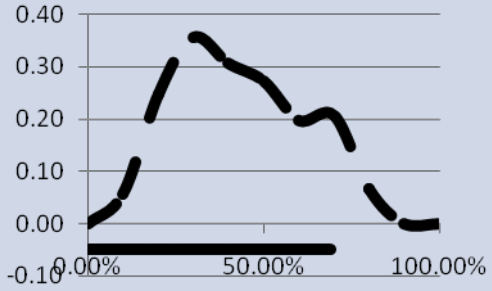
Left Biceps



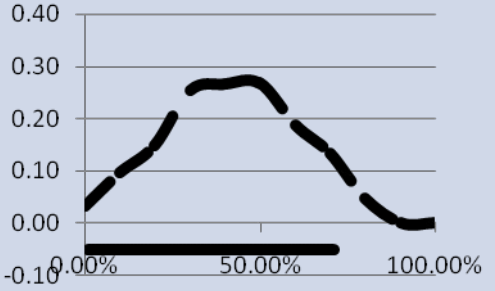
Right Biceps



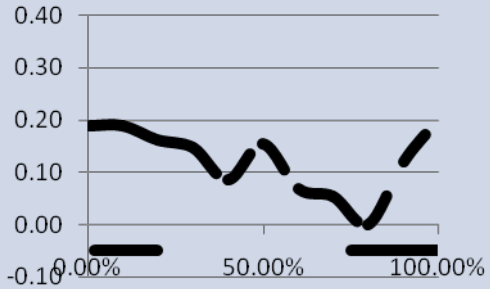
Left Pectoralis Major



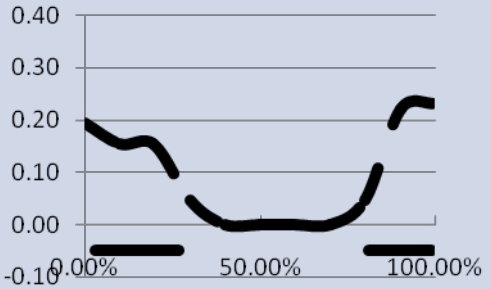
Right Pectoralis Major



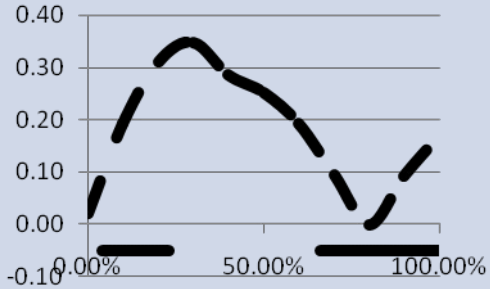
Left Posterior Deltoid



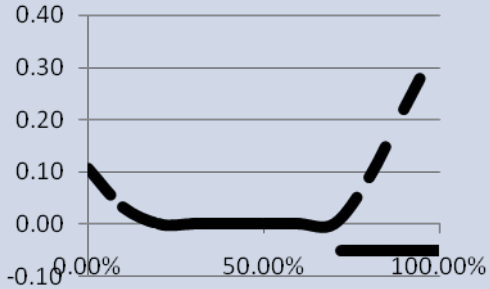
Right Posterior Deltoid



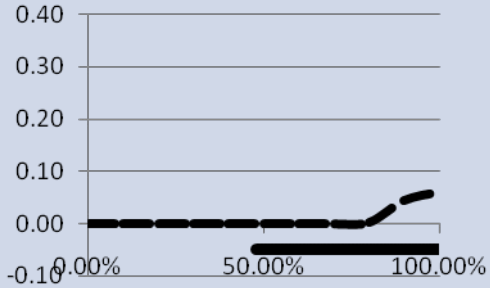
Left Trapezius



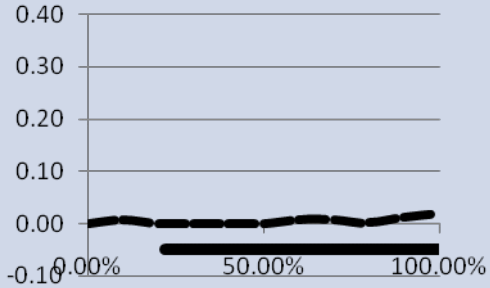
Right Trapezius



Left Triceps



Right Triceps



Mean Absolute Error (MAE)

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|MA_i - EA_i\right|$$

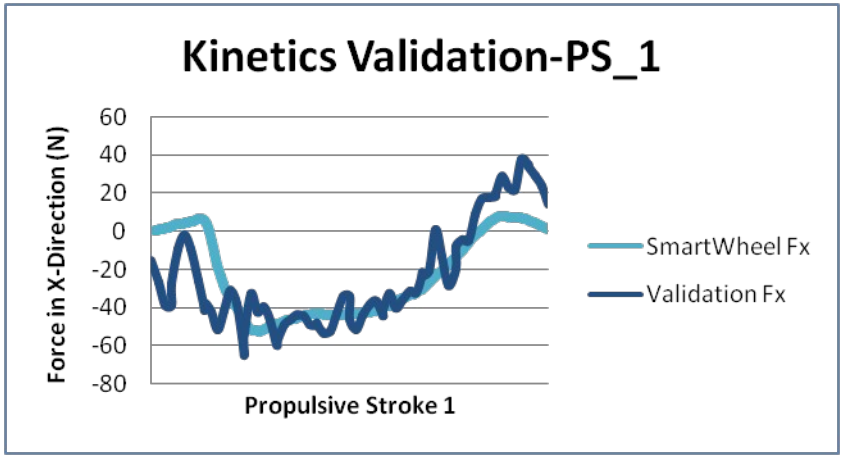
Previous reports[1] reported mean MAE for many tasks to be 0.078-0.139. My range is: 0.068-0.224 (neglecting the triceps). All our muscles were collected via surface electrodes; 6 of 10 in de Zee article were collected via fine-wire.

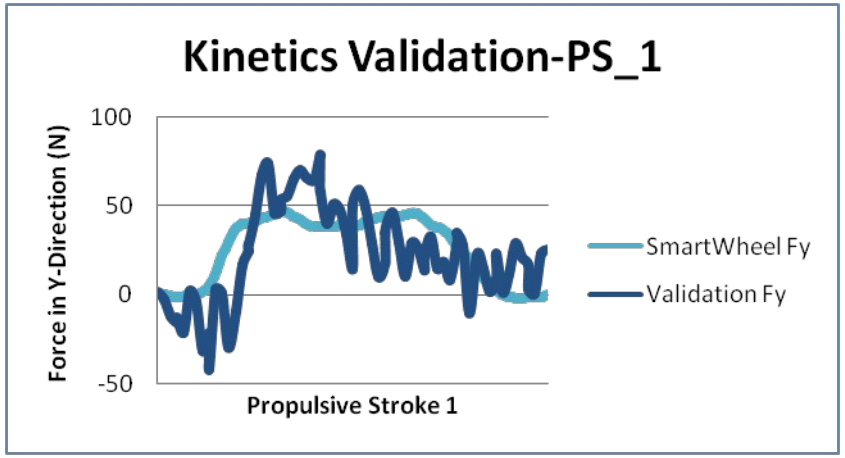
Muscles	Subject
Biceps left	0.138
Biceps right	0.224
Anterior Deltoid left	0.052
Anterior Deltoid right	0.070
Posterior Deltoid left	0.198
Posterior Deltoid right	0.096
Pectoralis Major left	0.068
Pectoralis Major right	0.094
Trapezius left	0.189
Trapezius right	0.078
Triceps left	0.558
Triceps right	0.547

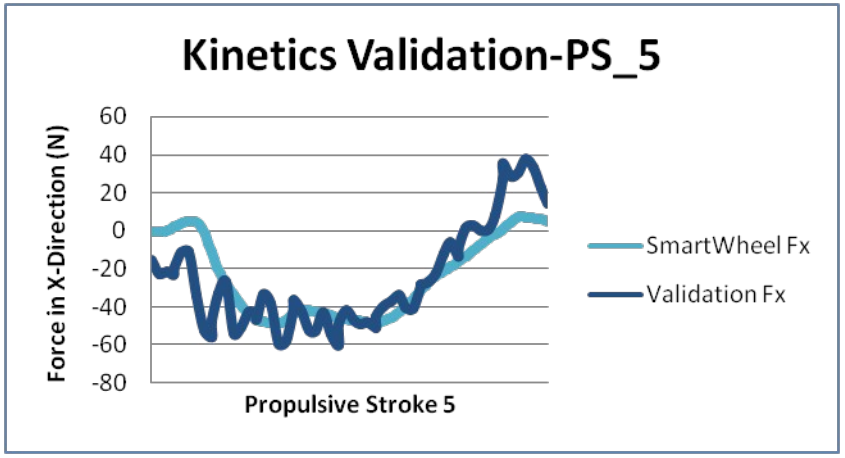
1. de Zee, M., et al. Validation of a musculo-skeletal model of the mandible and its application to mandibular distraction osteogenesis. Journal of Biomechanics. 40 (2007). 1192-1201.

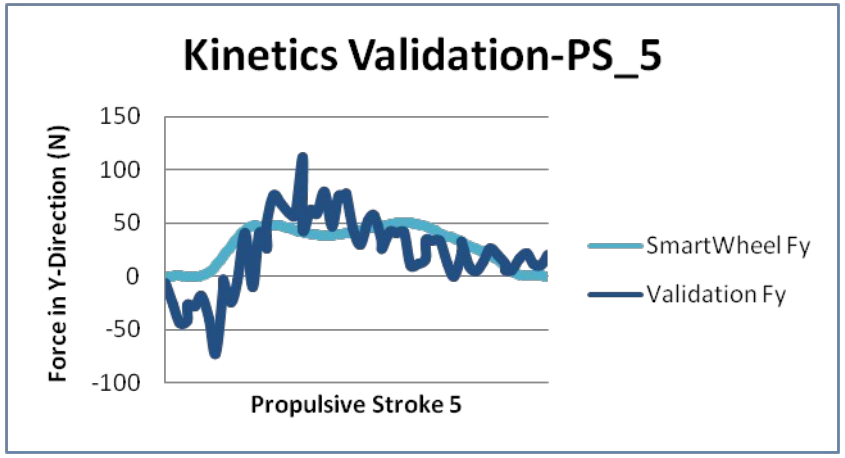
Validation (II) – Kinetics Comparison

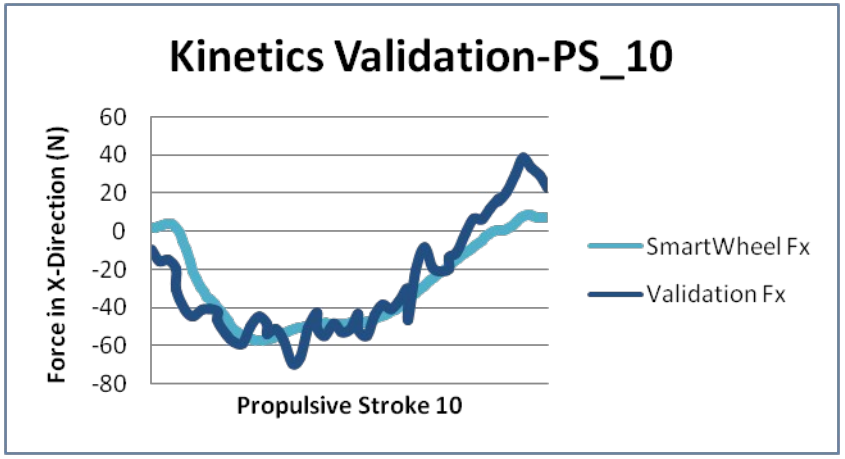
- Alter model inputs:
  - Calculate wheel torque (F_t) from SMART^{Wheel} data
  - Drive the model with this torque (and 3-D kinematics)
- Compare the resulting Fx, Fy, and Fz forces at the hand with the original SMART^{Wheel} data

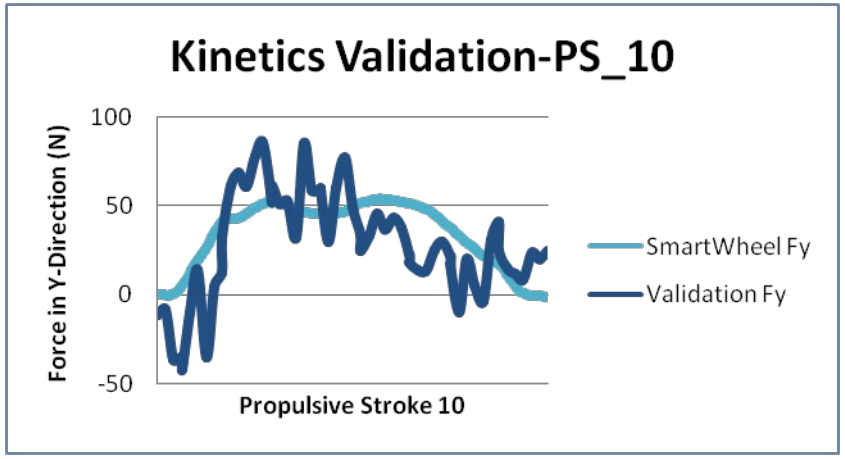

Kinetics Validation-PS_1
Force in X-Direction (N)
60
40
20
0
-20
-40
-60
-80
Propulsive Stroke 1
SmartWheel Fx
Validation Fx


Kinetics Validation-PS_1
Force in Y-Direction (N)
100
50
0
-50
Propulsive Stroke 1
SmartWheel Fy
Validation Fy


Kinetics Validation-PS_5
Force in X-Direction (N)
60
40
20
0
-20
-40
-60
-80
Propulsive Stroke 5
SmartWheel Fx
Validation Fx

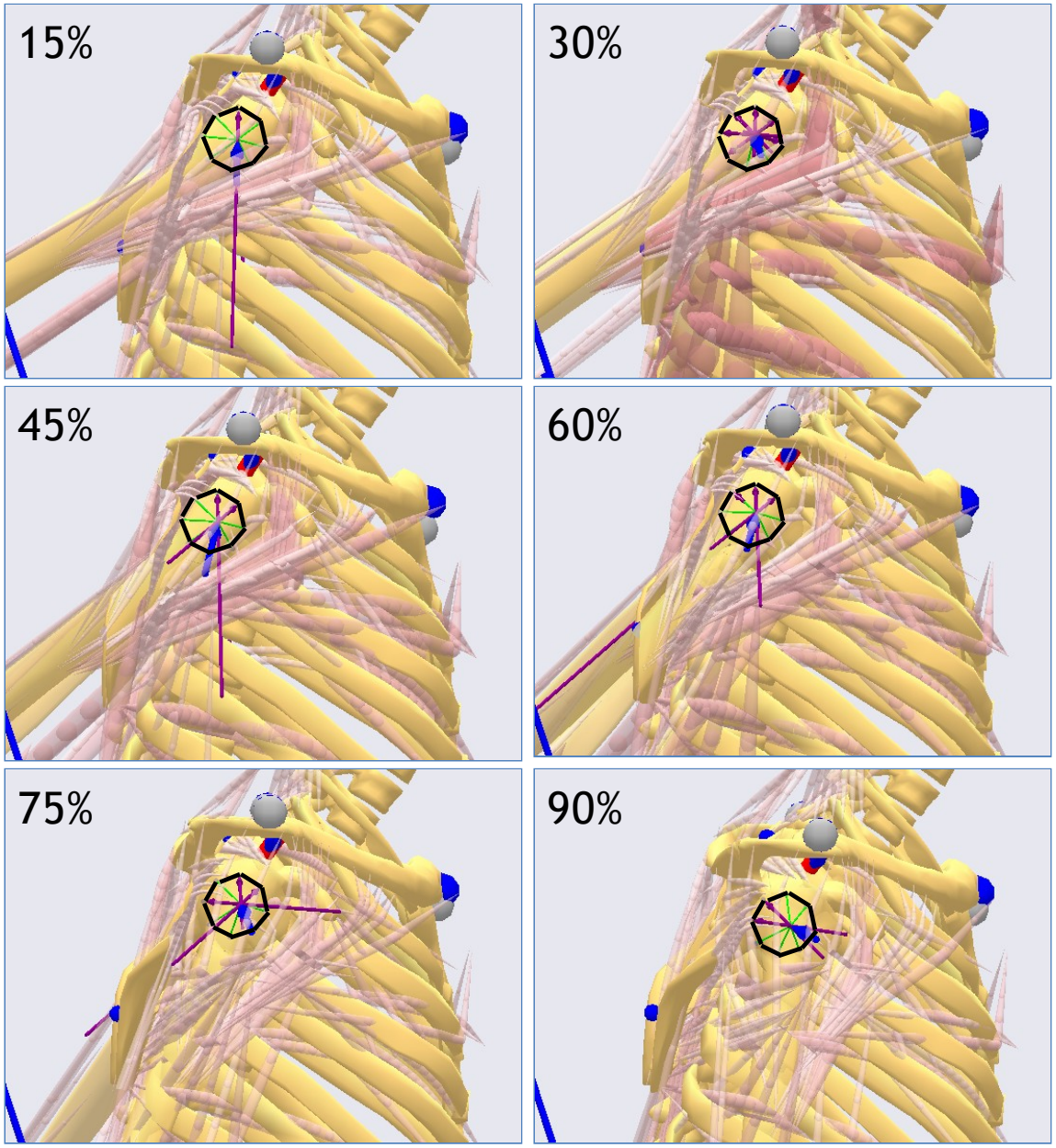

Kinetics Validation-PS_5
Force in Y-Direction (N)
150
100
50
0
-50
-100
Propulsive Stroke 5
SmartWheel Fy
Validation Fy


Kinetics Validation-PS_10
Force in X-Direction (N)
60
40
20
0
-20
-40
-60
-80
Propulsive Stroke 10
SmartWheel Fx
Validation Fx


Kinetics Validation-PS_10
Force in Y-Direction (N)
100
50
0
-50
Propulsive Stroke 10
SmartWheel Fy
Validation Fy

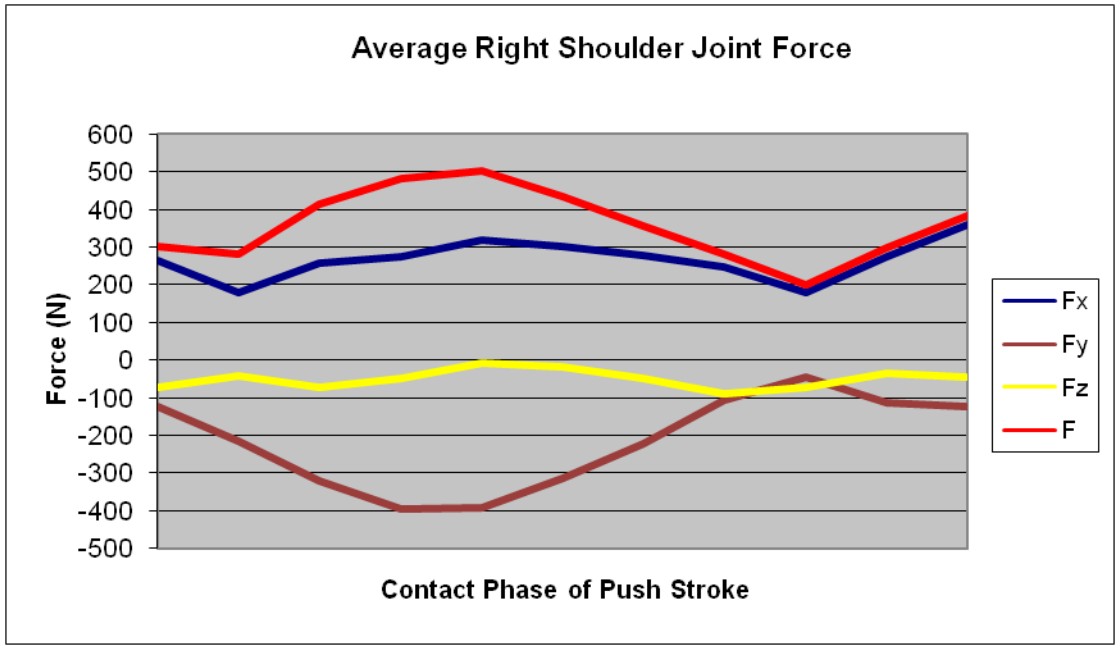
Shoulder Joint Investigation

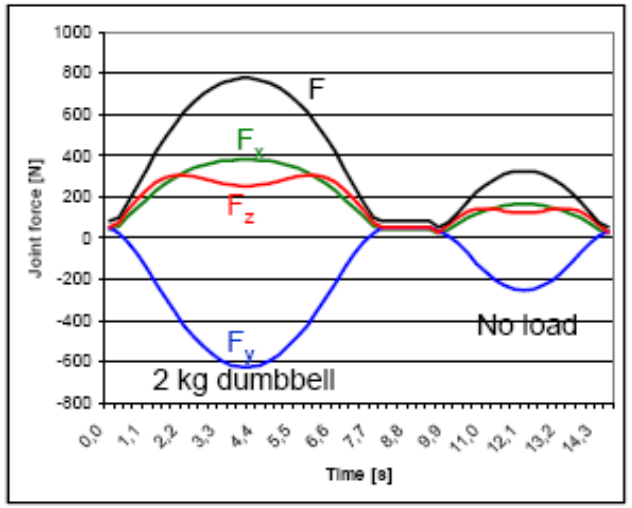
- Good matching between the computational and experimental muscle activities
- How do shoulder joint forces compare?
- Comparison to previous studies
  - Physiological in-vivo comparisons
  - Computational comparisons



- Transparent muscles and bones to allow us to look “into” the shoulder joint socket
- Green arrows: Boundaries of the glenoid cavity
- Black circles outline this defined area
- Blue arrow: Resultant force in the glenoid cavity
- Purple arrows: Force distribution in the glenoid cavity
- Shoulder joint forces at approximately 15, 30, 45, 60, 75,
and 90% of the contact phase of propulsion

Shoulder Joint Forces





2

Figure 2: Computed joint forces in the coordinate system and terminology of [1] using a quadratic recruitment criterion.

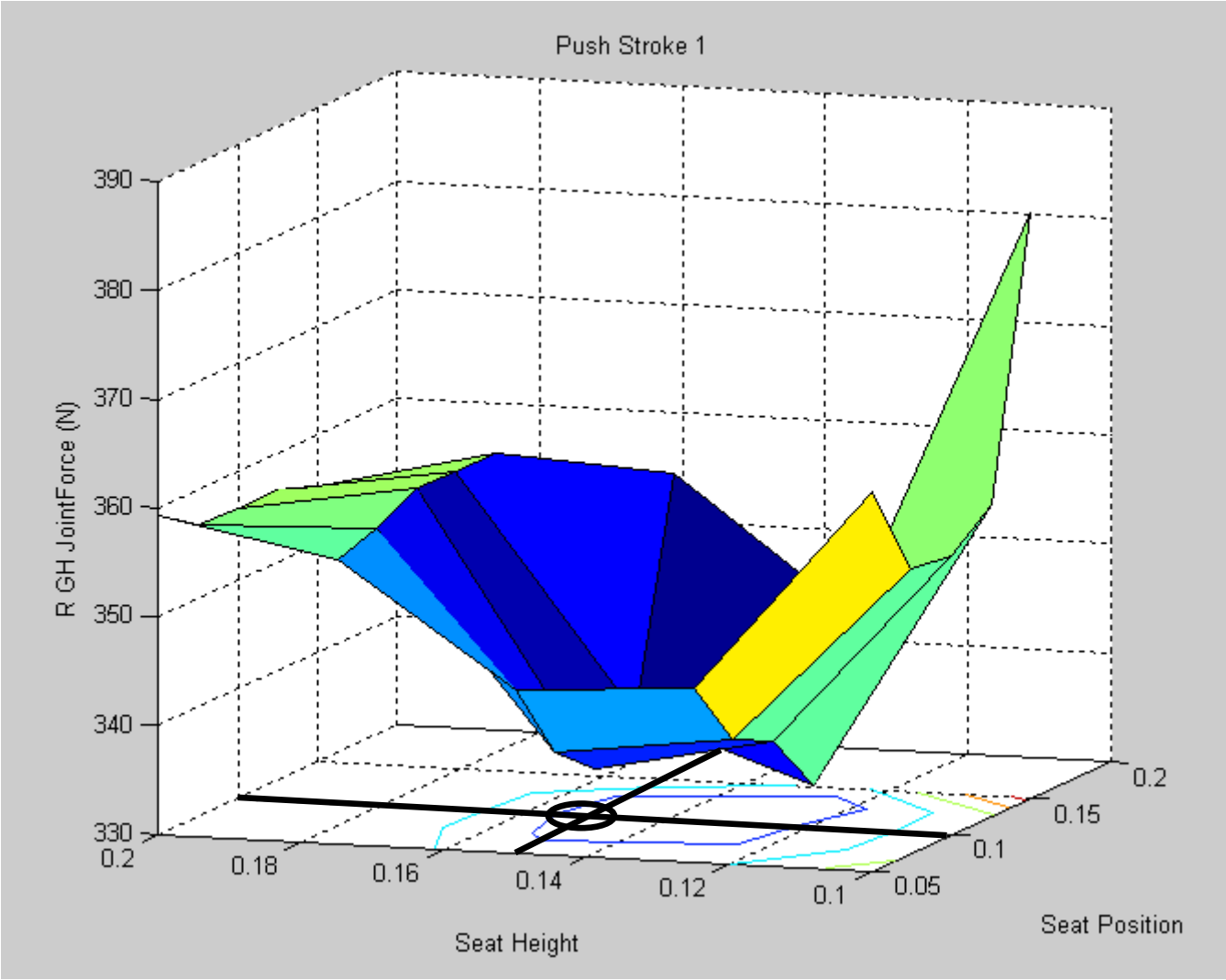
My results versus in-vivo validated results (above, right). The Fx, Fy, and Fz forces throughout 10% increments of the propulsive phase were averaged over 10 push strokes and graphed. Overall shoulder joint forces for both scenarios are of the same magnitude.

2. Rasmussen J., et al. Comparison of a Musculoskeletal Shoulder Model with In-Vivo Joint Forces. 2007 International Society of Biomechanics XXI Congress. Taipei, Taiwan. July 1-5, 2007.

Parametric Study

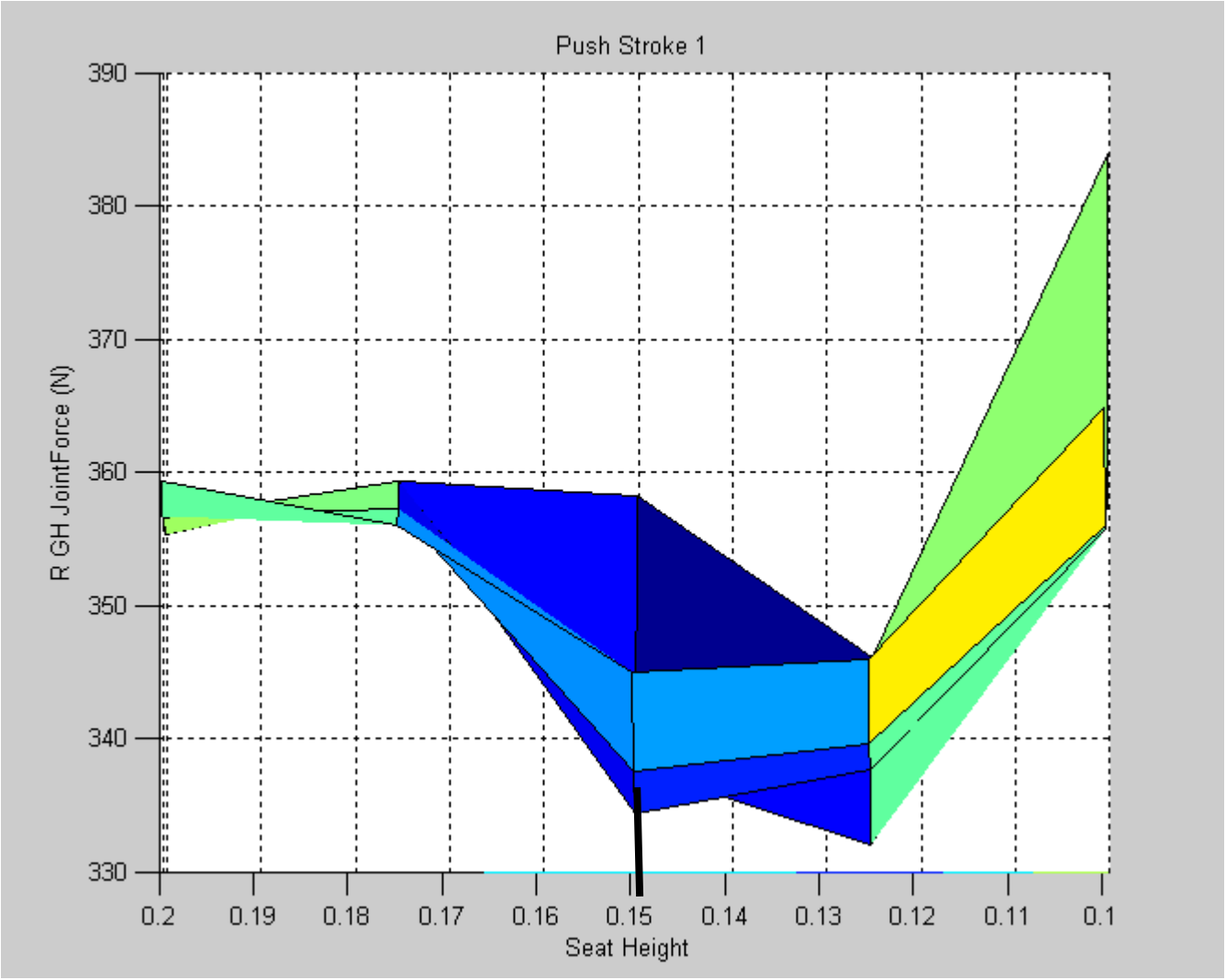
- Ran a parametric study looking at the shoulder joint forces at different axle placements. The axle placement was increased and decreased, in both height and anterior/posterior positioning, by 5 centimeters in all directions.

Parametric Results



Original axle placement is marked with intersecting

Parametric Results Cont.



Original seat height is marked by black vertical line. For this subject, the original axle placement is

Parametric Summary

- True minimum at a seat height 2.5 cm lower
- 2.38 N difference between ideal seat height and current seat height
  - Less than 1% (334.34 N – 331.96 N)
  - Is this significant?
- Axle placement 5 cm lower and more forward results in nearly 15% increase in joint load (334.34 N – 383.86 N).

Future Work

- Analysis of a model pre- and post- axle adjustment
  - Individual appears to have good axle placement
  - It is unlikely that everyone does
- Database of participants to analyze
  - Using model, find a subject whose axle placement is not ideal
  - Adjust axle-placement and compare pre- and post- shoulder joint forces

Q&A Panel

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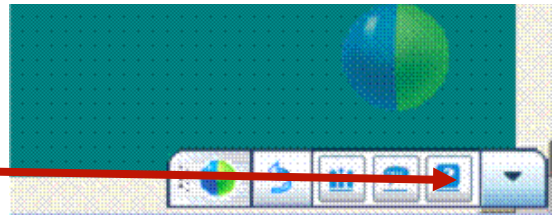
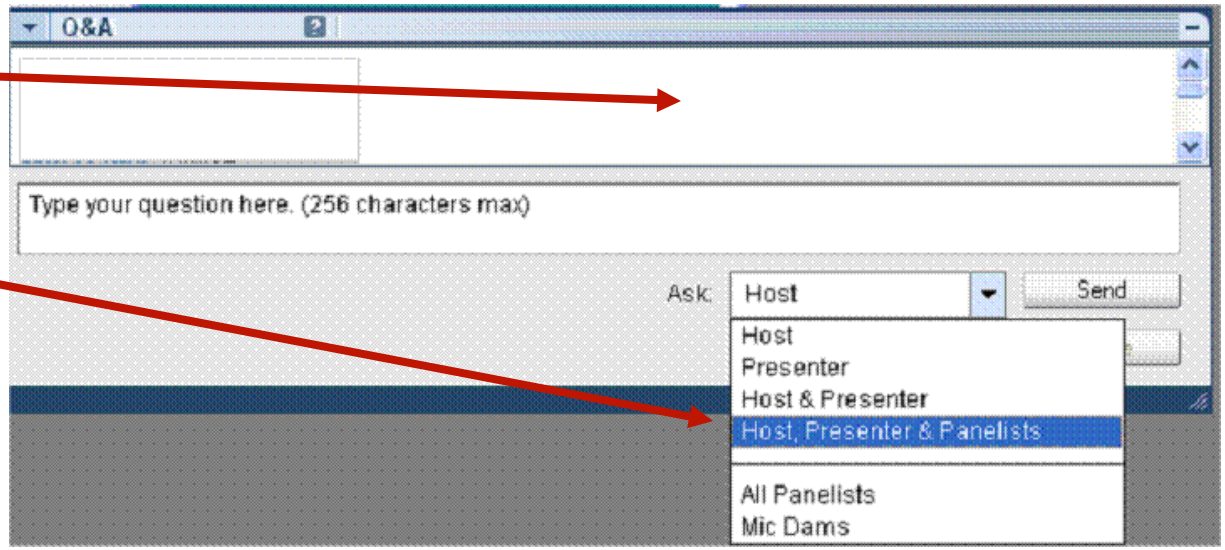
- Type your questions in the Q&A panel.
- Send the question to "Host, Presenter & Panelists"





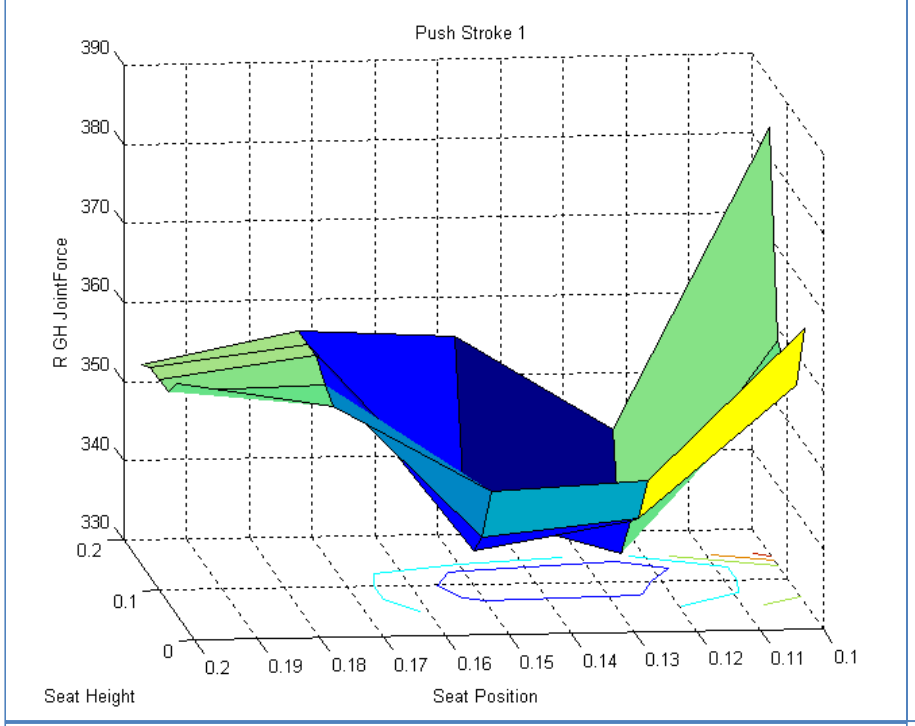
Notice the answer displays next to the question in the Q&A box. You may have to scroll up to see it.

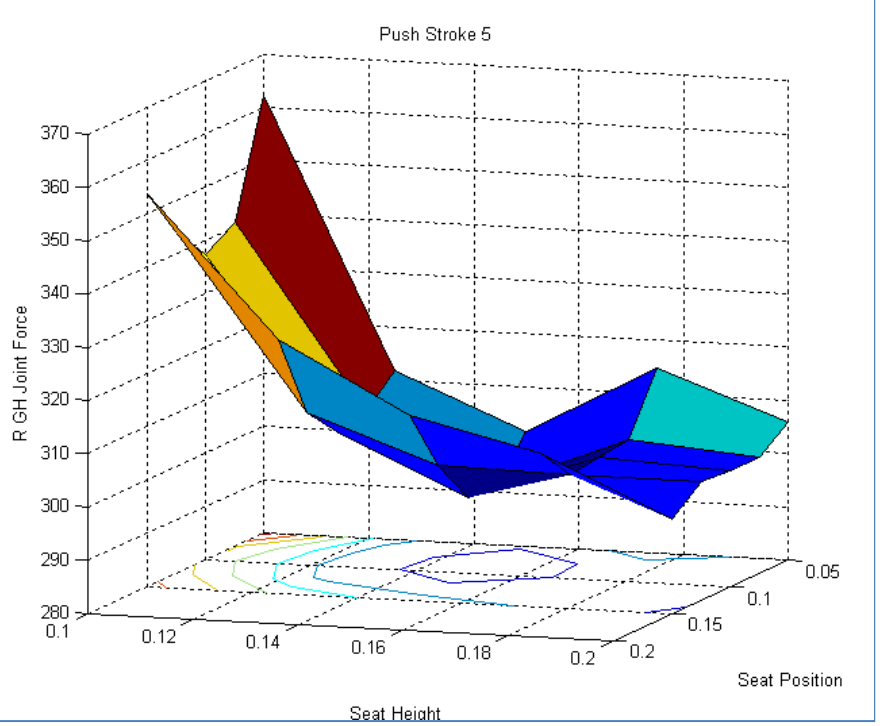
ANYBODY TECHNOLOGY

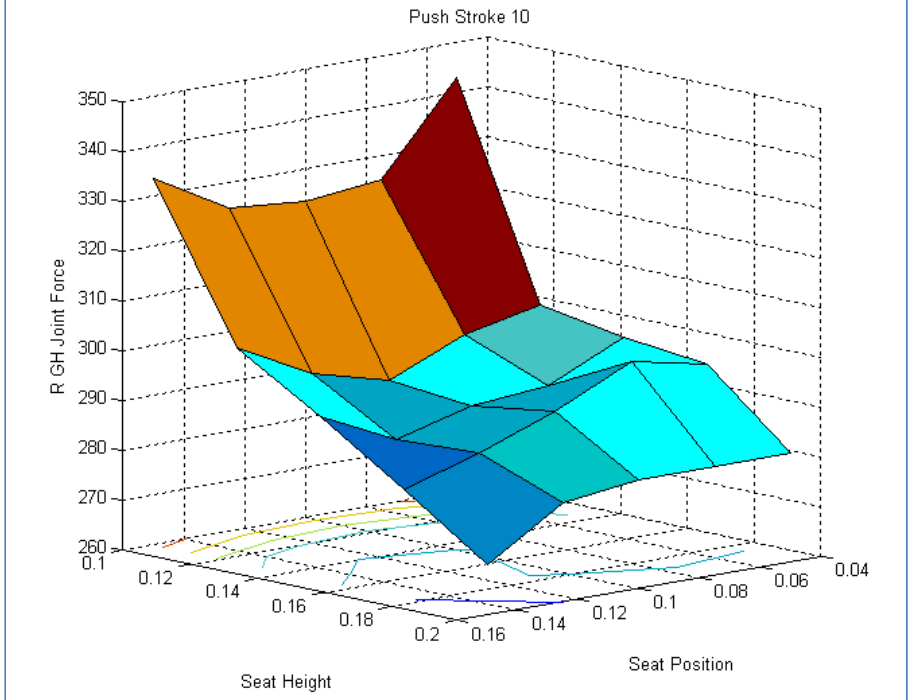
Acknowledgments

- Rutgers University
- Kessler Medical Rehabilitation and Research Education Center (KMRREC)
- Aalborg University and the AnyBody Project

Thank You!







- Multiple push strokes:
  - Different views
  - Don't anticipate