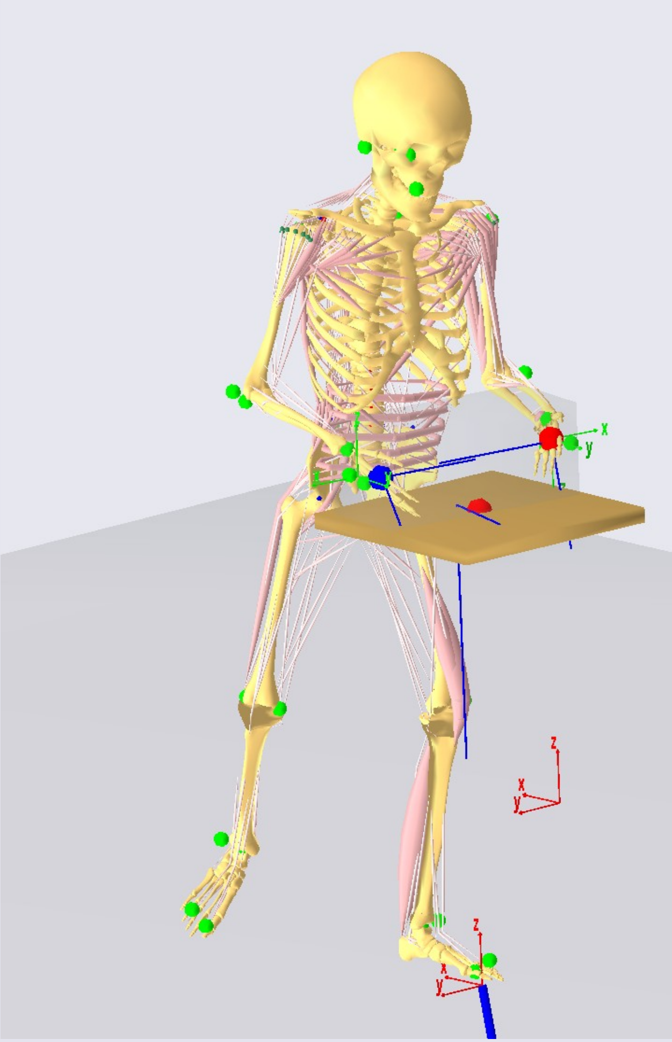
Motion Dynamics and Ergonomic Analysis



David Wagner

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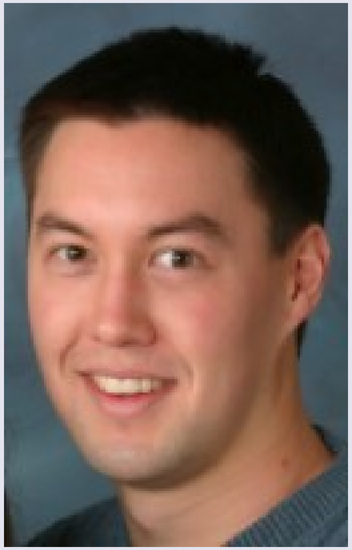

David Wagner
(Presenter)

Arne Klis
(Host)

John Rasmussen
(Panelist)

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Q&A Panel

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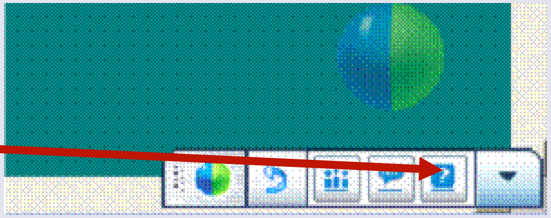

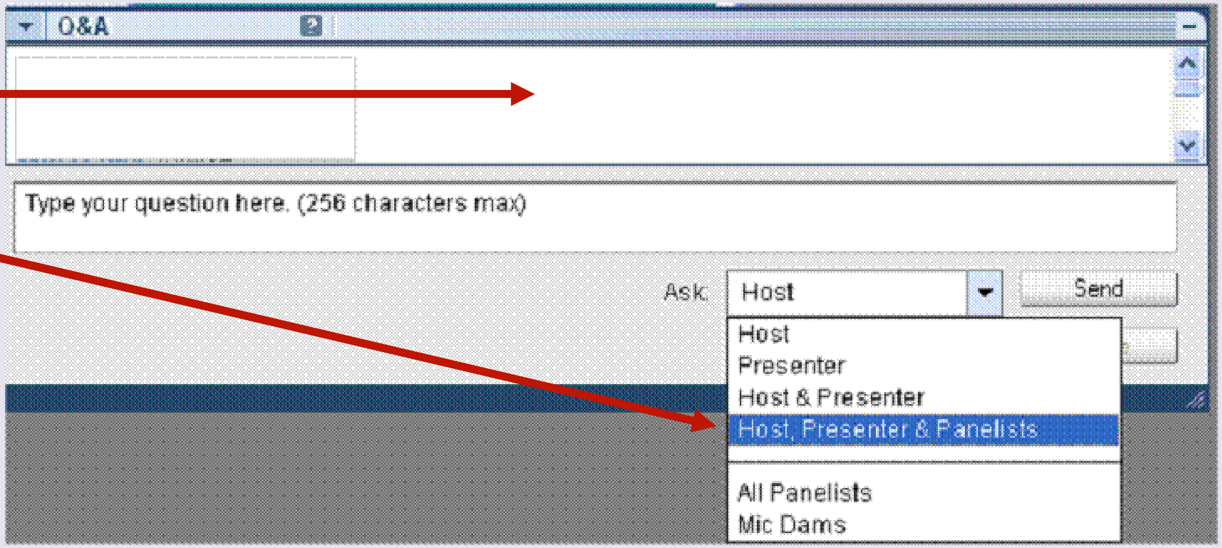

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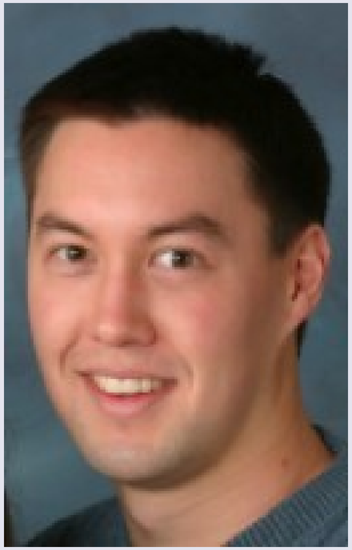
The presenter: David Wagner



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HUMOSIM LABORATORY
human motion simulation
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Questions to be Addressed

- Why am I doing this?
- How are human figure models used for ergonomics?
- Why doesn't everyone perform full dynamic analysis?
- What does our AnyBody model look like?
- Are there some quantitative results?
- What did I learn?

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Assessing the Importance of Motion Dynamics for Ergonomic Analysis of Manual Materials Handling Tasks using the AnyBody Modeling System

David W. Wagner, John Rasmussen, and Matthew P. Reed

Digital Human Modeling Conference
Paper # 2007-01-2504

http://www.sae.org/events/dhm/

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Ergonomics, and the Potential of Human Figure Models

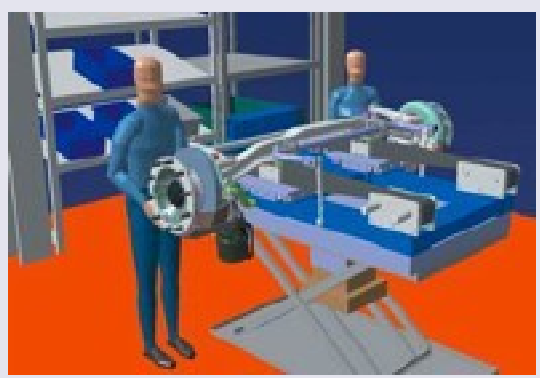
- Anthropometry
- Range of Motion
- Reach/Vision Capability
- Joint Moments
- Percent Strength Capable
- Joint Forces (I.e. low back compression)

Feasible

MoCap

Posture

Simulated (Representative)



Questions, it is ok to ask

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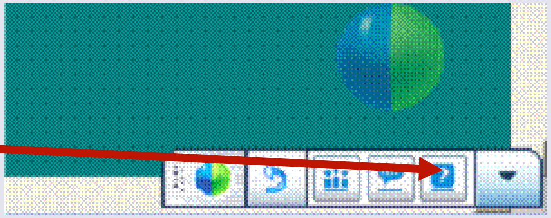

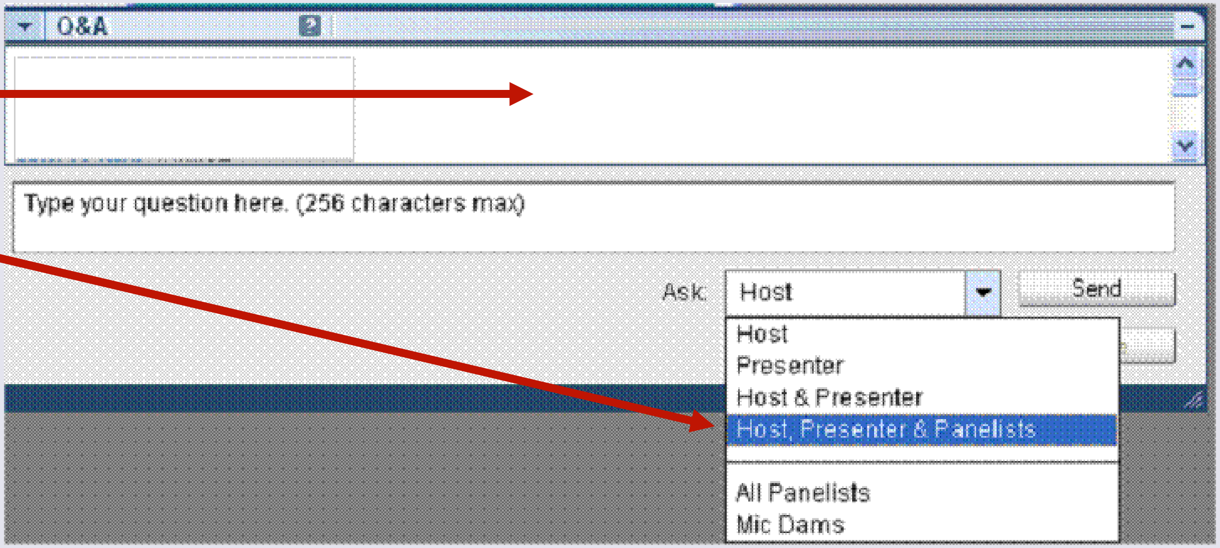

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The Premise of the Study

What can I do as an ergonomist with the capability of dynamic analysis, like that performed by the AnyBody Modeling Software?

-Is it helpful?

-Do I have all the necessary information?

-What are the potential time/benefits tradeoff?

Some Guidelines:

Attempt to use as many pre-defined models (as appropriate) as possible -> limit the amount of custom code

Attempt to keep models generic

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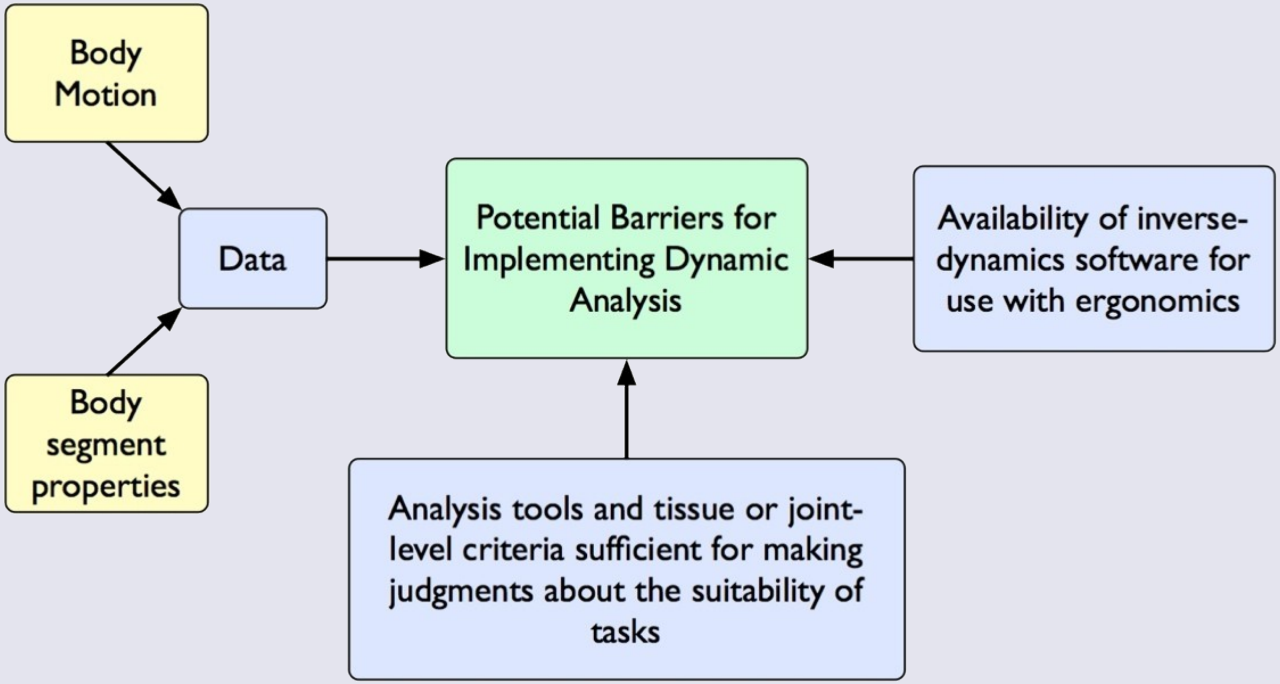
The Dynamic Challenge

The advantage of a dynamic analysis over static computations depend on the task characteristics => ambiguous

No quantitative criteria (i.e. acceleration limit, maximum momentum) to guide selection of dynamic over static => not intuitive

Assessing the validity of the static assumption is left up to the ergonomist

Most of the commercially available tools used for ergonomic analysis do not have the capability to perform dynamic analysis



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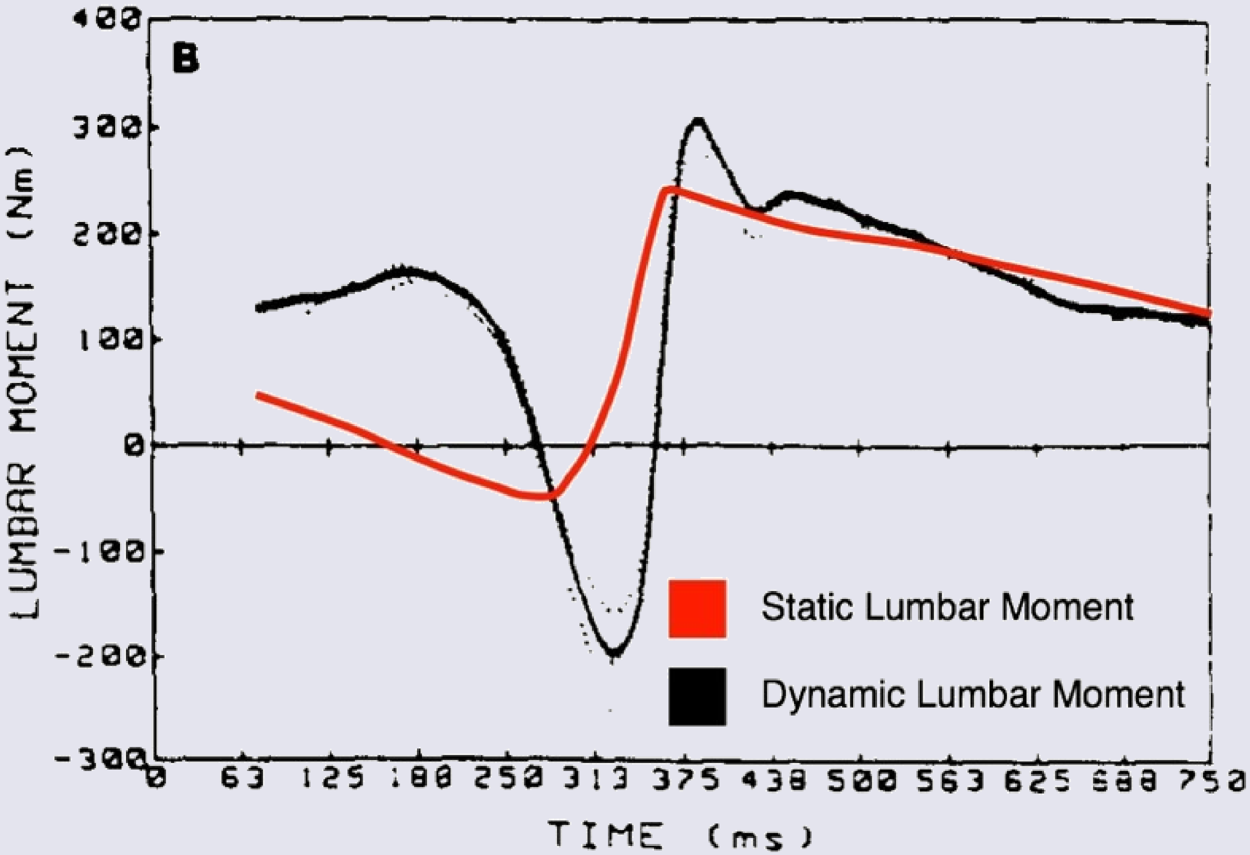
When Should I Include Dynamic Effects?



The dependence of the importance of dynamic effects on task characteristics is not straightforward (Dysart and Woldstad (1996), McGill and Norman (1985)). Additionally, it is difficult for an ergonomist to determine if a task analysis requires a dynamic analysis or conversely if a static analysis will suffice.

Problem Review

Analysis Mode	Assumptions	Input
Static	Input is assumed to be associated with greatest injury risk or tissue stress for the duration of the task	Single Posture (representation of whole body configuration, segment mass distribution, segment COM positions)
Quasi-Static	Static Analysis is applied at multiple time steps where inertial effects are neglected	Sequence of Postures (same as above)
Dynamic	Realistic representation of changing velocity and acceleration profiles of body segments	Motion (same as above, segment moments of inertia)

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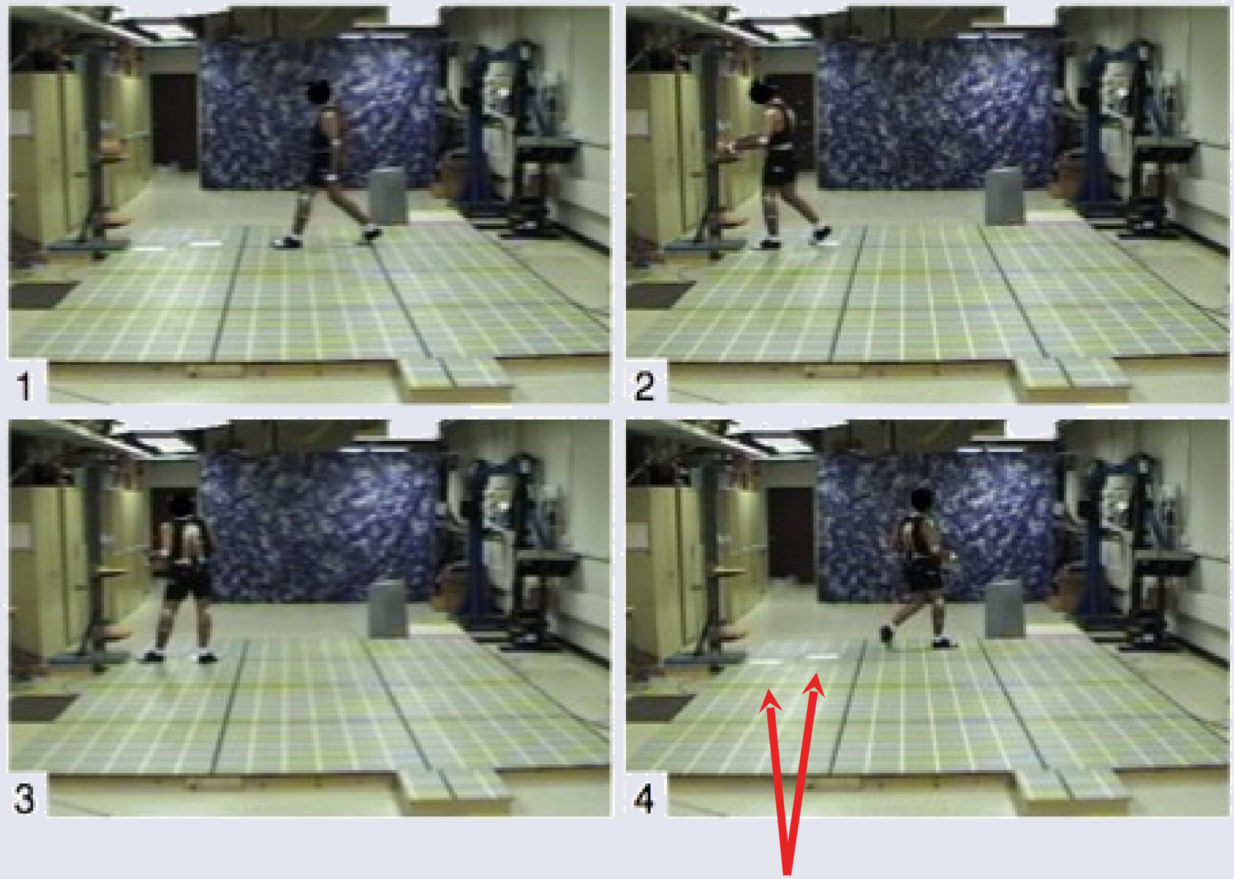
Data Collection

Lifting Task
Two handed box
Load Mass: 4.54 kg
Load Dimensions:
 0.295 x 0.2 x 0.186 m
Shelf Height: 0.967 m

Male Participant
Age: 23 years
Stature: 1.824 m
Body Mass: 84.55 kg



Force Plates

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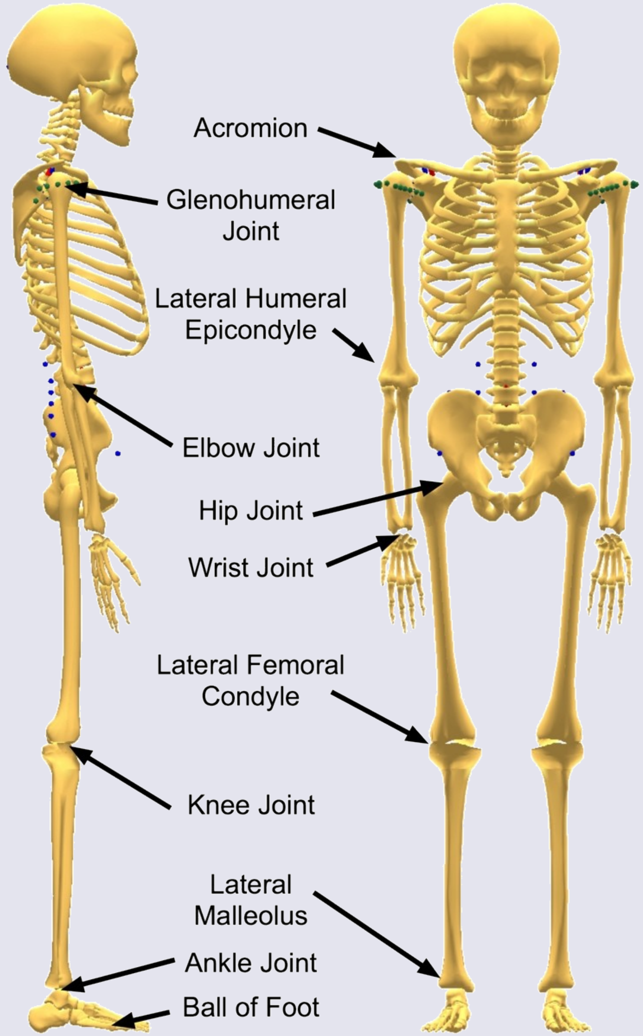
Our AnyBody Model

Manikin Segment	Joint	DOF	Single DOF Definition	Kinematic Driver (Positional or Angular)
Pelvis	Global Reference	6	Position (x,y,z) Rotation(θ,φ,ψ)	Positional Angular
Thorax	Thorax-Lumbar Spine	3	Lat. Bending Rotation Extension	Angular
Neck	Cervical Spine	1	Extension	Angular
Clavicle	Sterno-Clavicular	3*	Protraction Elevation Axial Rot.	Angular
UpperArm	Gleno-humeroid	3	Abduction Flexion External Rot.	Positional
ForeArm	Elbow	2	Flexion Pronation	Positional Angular
Hand	Wrist	2	Flexion Abduction	Angular
Thigh	Hip	3	Flexion Abduction External Rot.	Positional
Shank	Knee	1	Flexion	Positional
Foot	Ankle	2	Plantar-Flexion Eversion	Positional



Anatomical positions used to drive the AnyBody manikin

Anthropometric Model Scaling

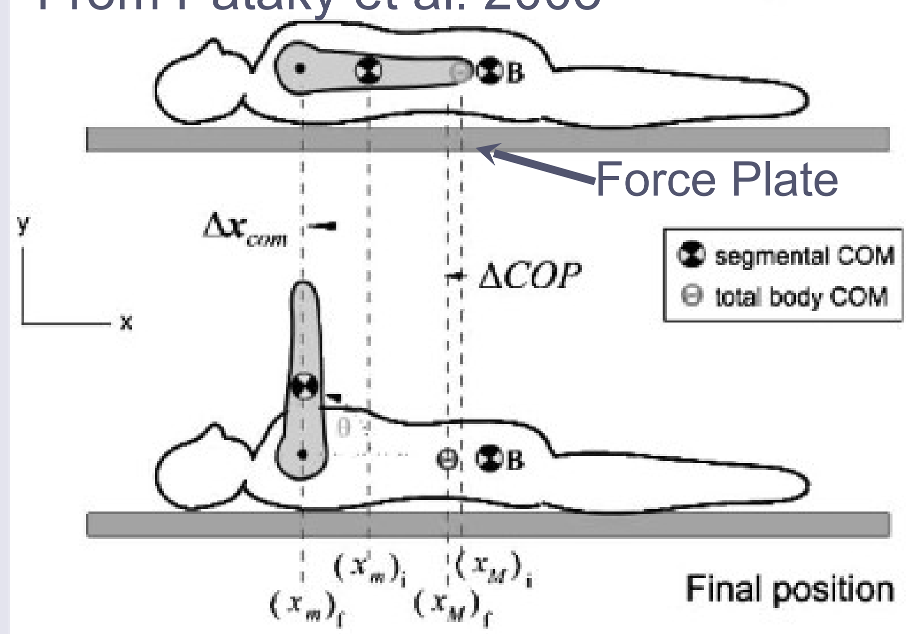
Mass Scaling Measure	ScalingUniform Values (% Body Mass)
Lower Lumbar Spine	4.08
Upper Lumbar Spine	4.62
Lower Thoracic Spine	5.09
Upper Thoracic Spine	6.51
Lower Cervical Spine	0.51
Upper Cervical Spine	0.43
Pelvis	14.2
Clavicle	2.37
Upper Arm	2.8
Lower Arm	1.6
Hand	0.6
Head	8.1
Thigh	10.0
Shank	4.65
Foot	1.45
Ball of Foot	0.0

Lower Arm + Hand: 2.2 / 2.391

Shank + Foot: 6.1 / 6.55

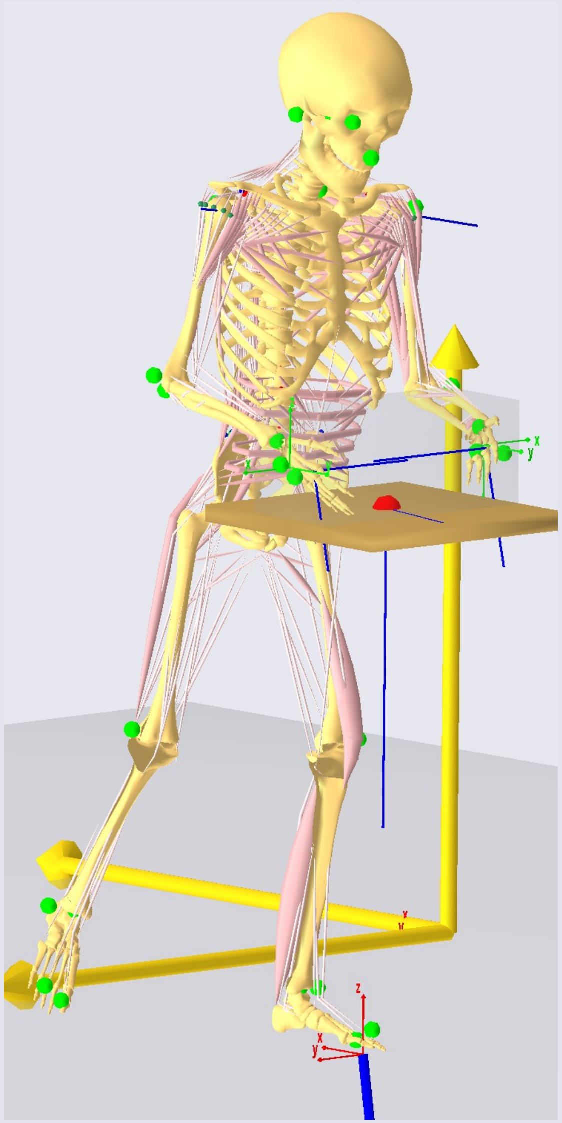
Segment mass parameters were defined by using the same scaling as that of a mid-size male.

From Pataky et al. 2003



$$m = M\left(\frac{\Delta \mathrm{COP}}{\Delta x_{\mathrm{com}}}\right)$$

Anthropometric Model Scaling (con't)



With Muscles

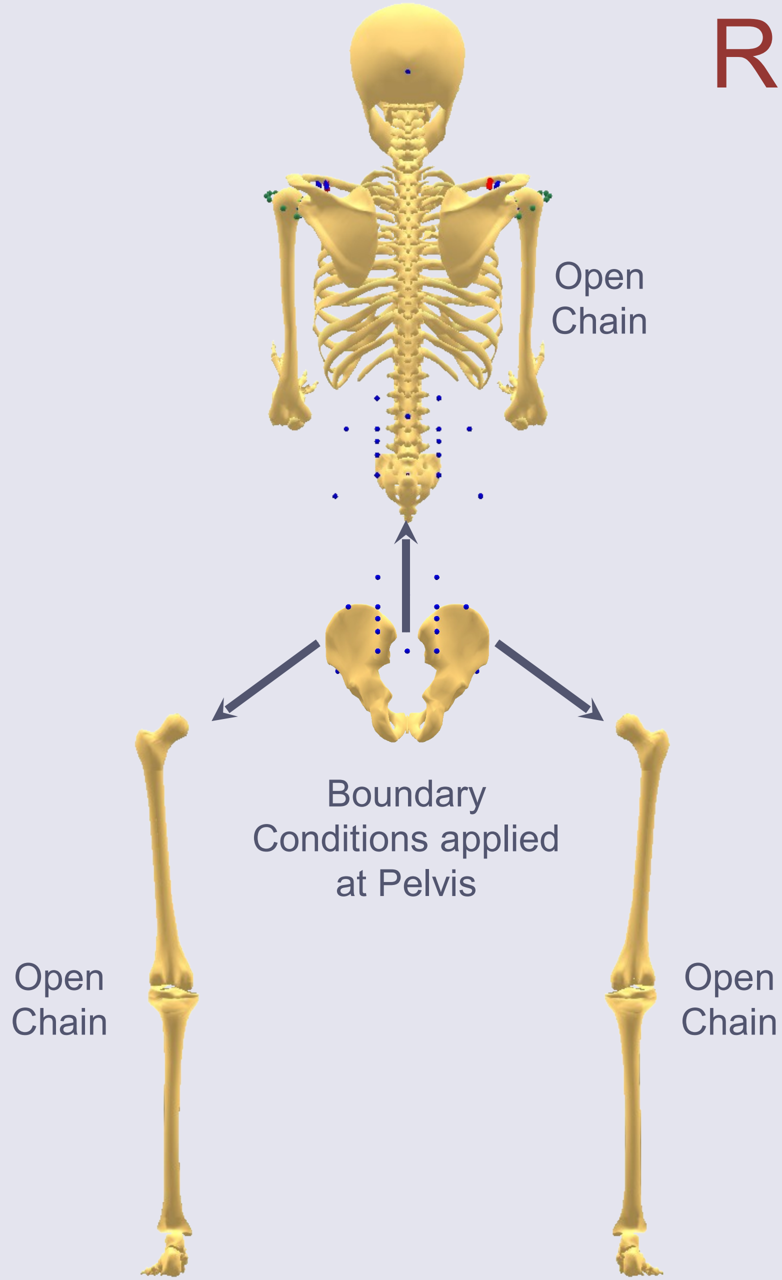
Geometric Scaling Measure	ScalingUniform Values (m)
Thigh Length	0.4901
Shank Length	0.4528
Foot Length	0.2106
Pelvis Width	0.1520
Head Height	0.16
Trunk Height	0.6674
Upper Arm Length	0.3117
Fore Arm Length	0.2931
Trunk Width	0.421

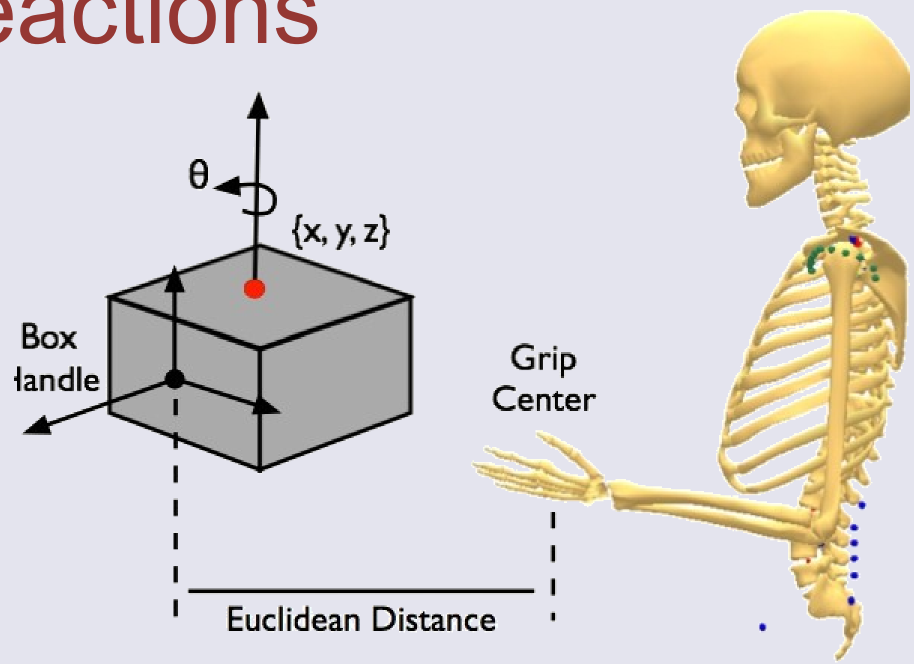
Residual for remaining stature

Shoulder to Shoulder Distance

AnyBody Technology

Model Kinetics and Environment Reactions





Load motion is driven by left and right grip positions truncated by the pickup and delivery times.

Ground/Foot forces are modeled as spatially translating resultant forces applied to the foot segment at the location of the COP with equal and opposite magnitude as measured by the force plate.

COP position is driven as a calculated measure from the individual force plates.

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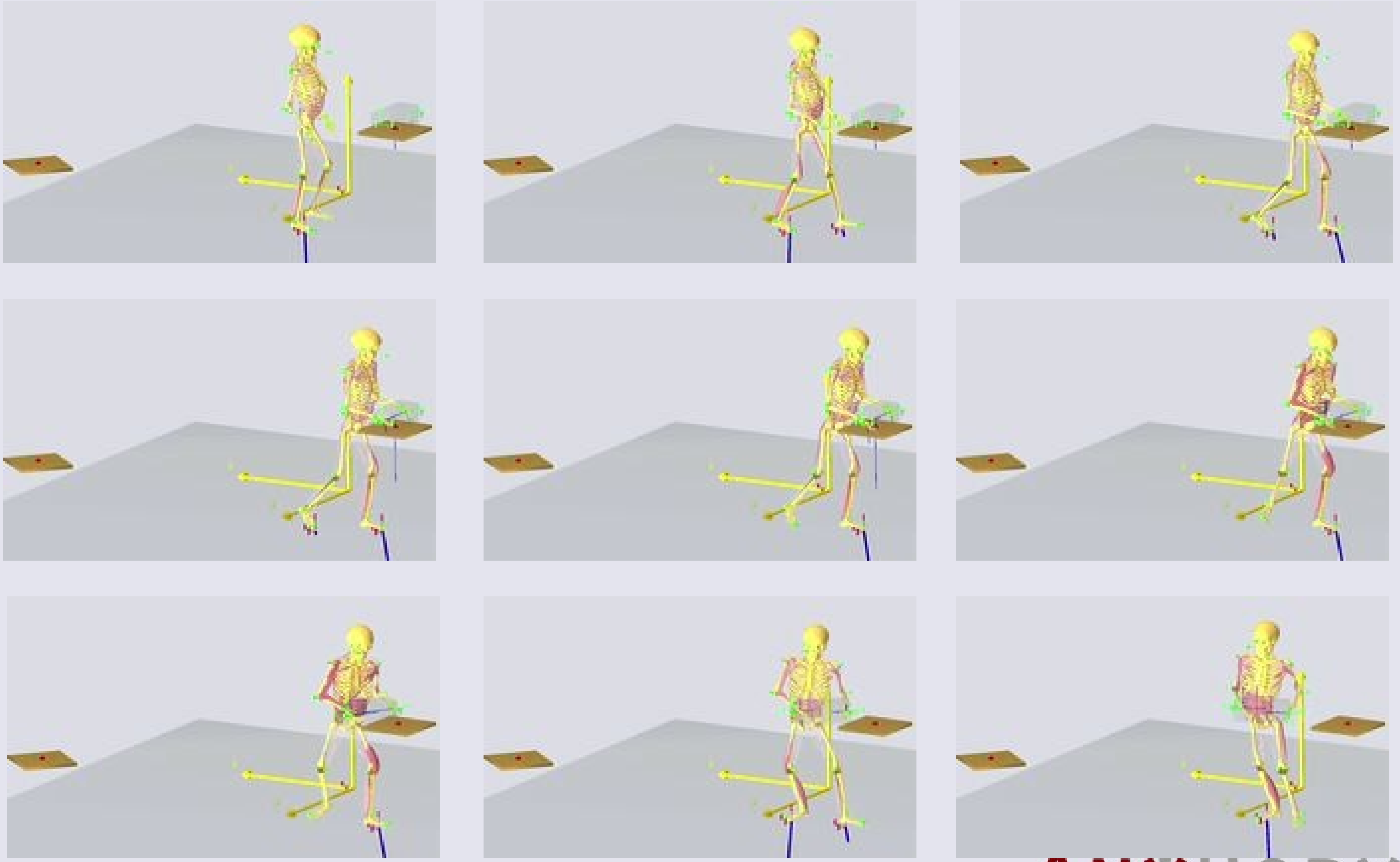
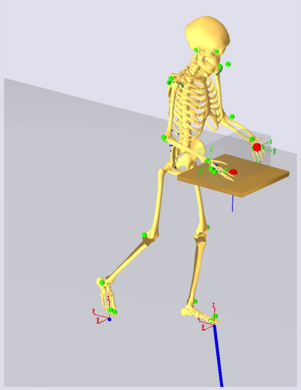
Dynamic simulation



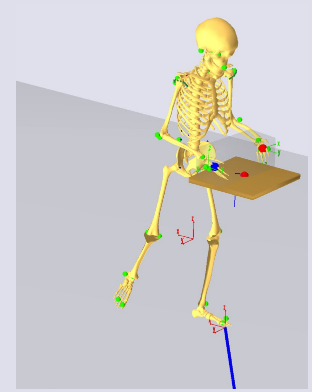
Results

Dynamic

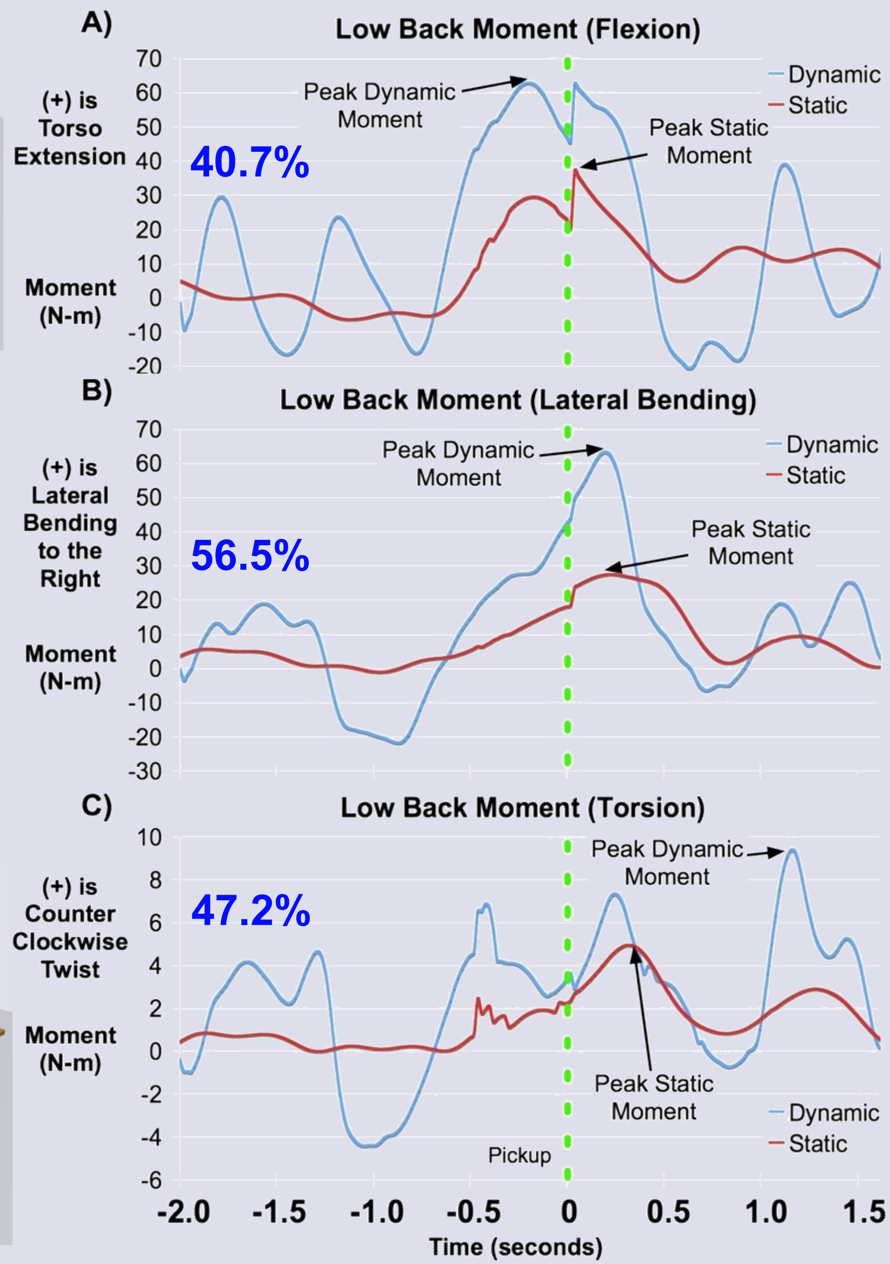
Static

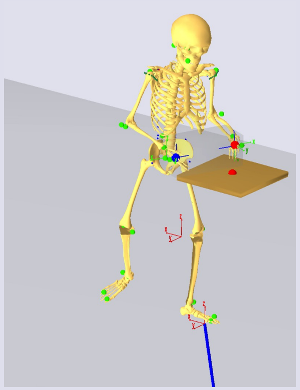


-0.20

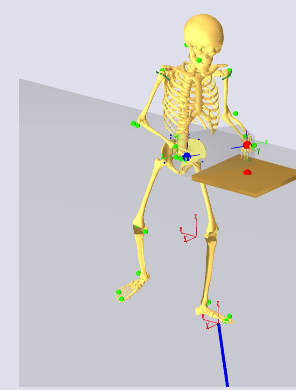


0.04

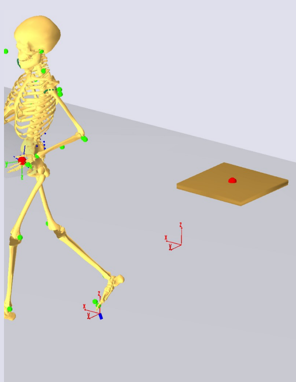




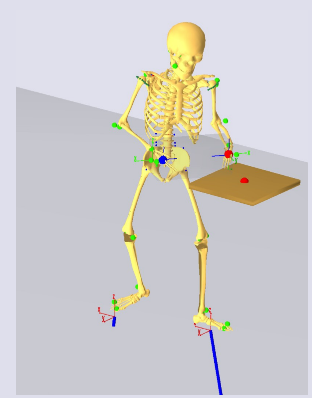
0.20



0.22



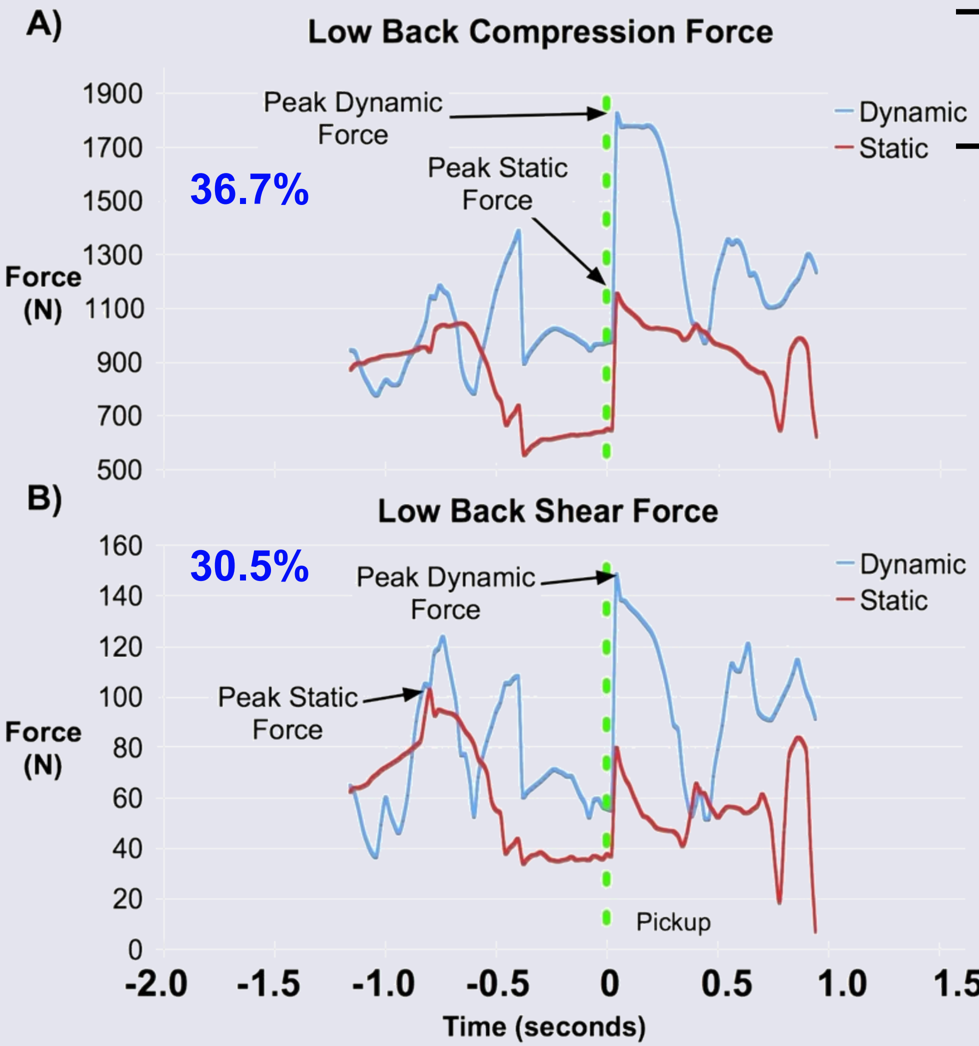
1.14



0.32

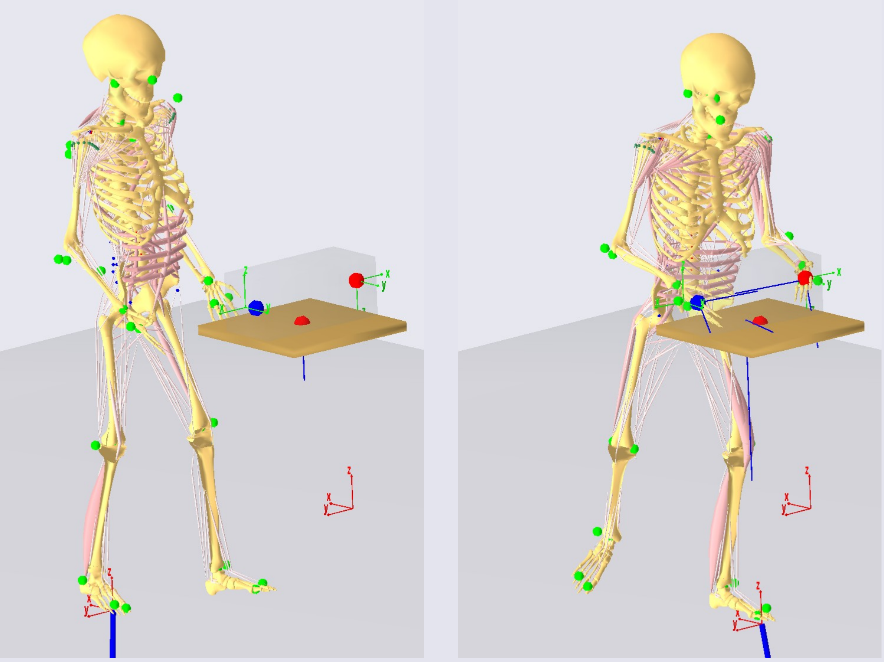
Results

Percent by which static analyses underestimates peak dynamic forces



	Dynamic Low Back Forces (N)		*Quasi-Static Low Back Forces (N)*	
Time (s)	**Compression**	**Shear**	**Compression**	**Shear**
-0.80	1145.4	104.3	943.3	**102.9**
0.04	**1822.4**	**147.9**	**1152.8**	79.31

Predicted low back forces are measured at the L5-Sacrum joint



-0.80

0.04

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Discussion

Study	Lifting Weight (kg)	Lifting Position	Foot Constraints	% Underestimation of Dynamic Peak Flexion
Current	4.54	Waist level	Unconstrained, Pickup transfer (135° turn)	**40.7%**
McGill and Norman (1985)	18	Waist to mid-chest; 83 cm anterior from the edge of the table	Unconstrained, Pickup stay (no turn)	16% (averaged over 4 subjects)
Tsuang et al. (1992)	5.1	Floor to waist and 47 to 70 cm transfer measured anteriorly from the ankle	Parallel Stance (no turn)	34.5 % (maximum over 10 subjects)
Plamondon et al. (1995)	11.6	22 cm off the floor (deliver to 80 cm high shelf)	Parallel Stance, Pickup transfer (90° to 180° twist)	*4.1% (maximum over all trials)

Peak low back compression of 1822.4 N (dynamic) versus 1152.8 N (static) yield same conclusion relative to safe lifting criteria set by NIOSH, (< 3400 N compression force).

*Implication of this analysis is that quasi-static analyses may fail to identify some jobs that exceed that criteria.

Kinematic Modeling in AnyBody

Kinematic redundancy must be handled at the software level and not by the user (in progress).

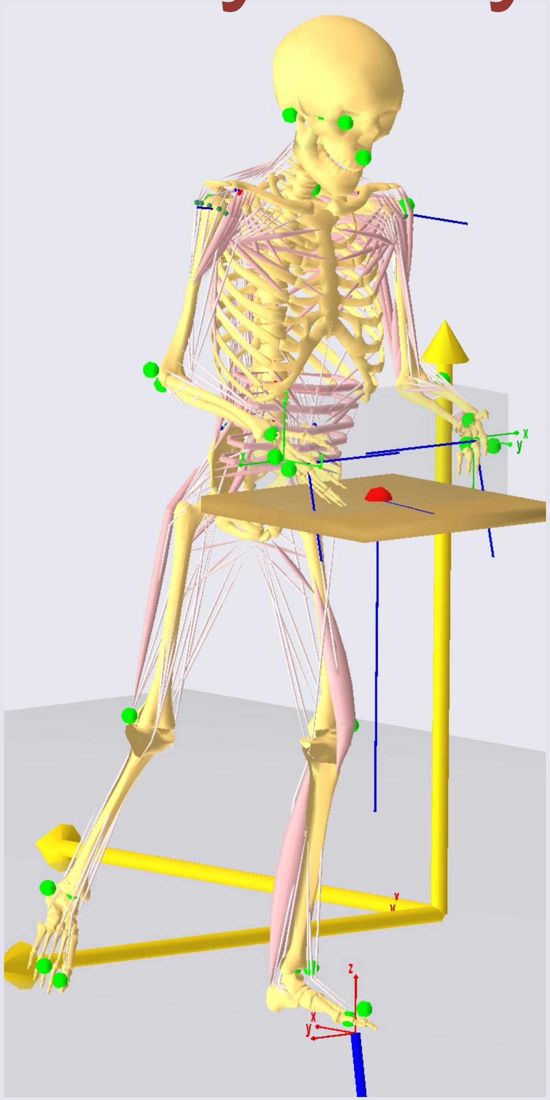
Predefined functions for model scaling were limited. Allow for capability to scale body dimensions as available.

Utilization of a published standardized set of anthropometric parameters for whole body scaling would improve the overall model generality and accuracy.

Separate Body and Application Repositories are beneficial when developing new models.

Open model repositories allow for potential for improving/building on previous AnyBody models.

Command line interface allows for potential inteface with other human modeling and analyses software.



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The Future of Dynamic Effects

Inertial effects do affect model estimates muscle forces and joint moments.

Currently, motion capture is the only way to generate quantitatively realistic motions of sufficient quality for inverse-dynamics analysis.

Motion simulation software must be improved to accommodate realism in not just posture, but in the velocity and acceleration domains of prediction as well.

This work has not demonstrated that ergonomists are currently failing to diagnose dangerous jobs by not including dynamic effects.

Including dynamic effects in analysis tools will only be helpful if acceptability or tolerance criteria based on dynamic considerations are further developed.

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Further information

- Modeling discussions and support:
  tech.groups.yahoo.com/group/anyscript
- Papers, references and models:
  www.anybody.aau.dk
- Software downloads, documentation, newsletter:
  www.anybodytech.com

- Human Motion Simulation Laboratory (HUMOSIM):
  www.humosim.com
- David Wagner (presenter):
  www.umich.edu/~dwwagner

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Thank You for Listening

Special Thanks to:

Advisors: Matt Reed and Don Chaffin
John Rasmussen
Arne Klis
AnyBody Panelists
HUMOSIM partners:

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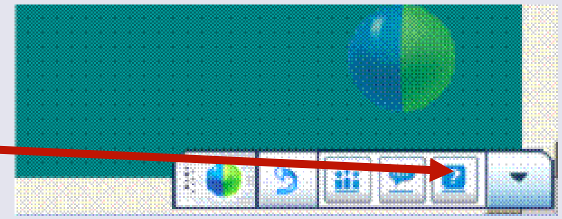

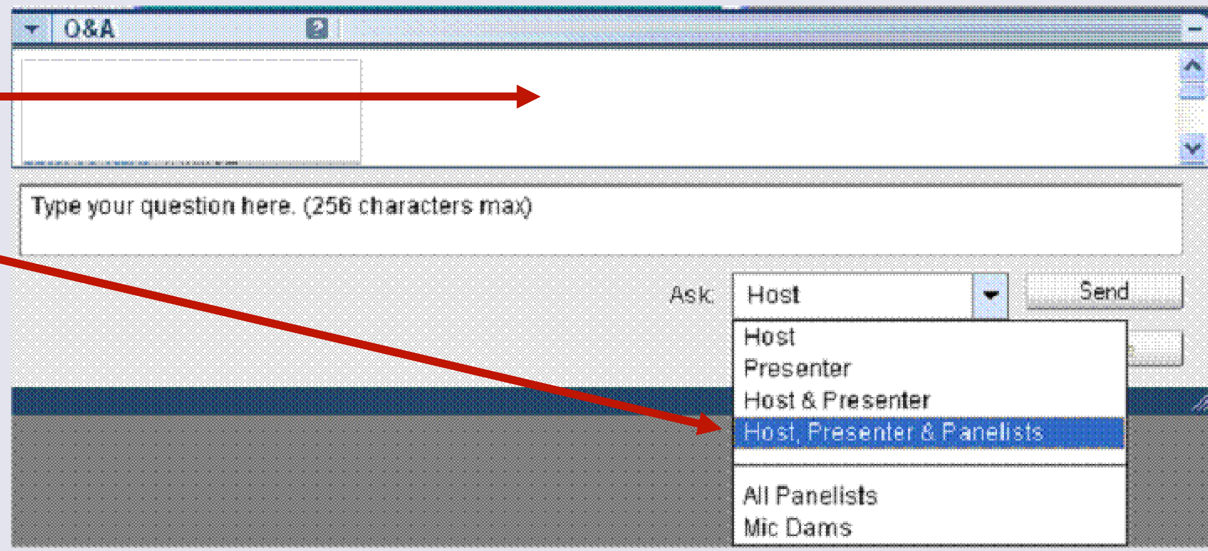

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