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Feasibility of the Lifting Full-Body Model to Simulate Squatting Tasks

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Introduction

Low back pain is one of the most common injuries experienced by healthcare workers who perform manual patient-handling tasks. These tasks require caregivers to squat, lift, lower, and reposition patients, which may replace high loads at the low back, increasing their risk of injury[1]. Experimental studies of these tasks can be extended with a computational model of the lumbar spine. Currently, there is not a freely available subject-specific model for patient-handling tasks. Work-in-progress from a proof-of-concept study to determine the feasibility of the OpenSim[2] Lifting Full-Body (LFB) Model[3] to simulate squatting tasks is presented.

Methods

Subject One 20-year-old able-bodied female volunteer. The subject weighed 56.7 kg and her height was 63 in.

Experimental Set-Up

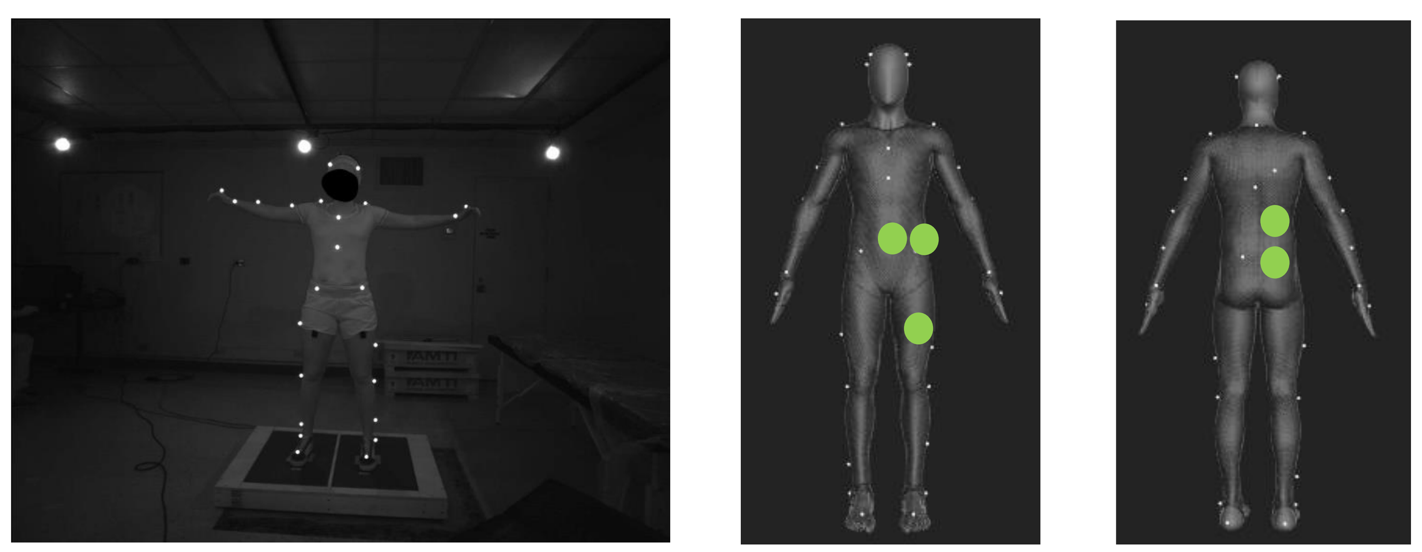

Figure 1 (Left): While performing squats, the subject stood with each foot on a force plate. (Center and Right) Ten EMG sensors were placed bilaterally on the following muscles: lumbar erector spinae, thoracic erector spinae, rectus femoris, rectus abdominis, and the external obliques. Marker data were collected at 100 Hz and EMG and kinetic data were collected at 1000 Hz. The subject performed five consecutive squats per trial, for a total of four trials.

Data Processing

- Kinetic data down-sampled to 100 Hz
- Kinematic, kinetic, and EMG data filtered with a 4th order Butterworth filter, cut-off frequency of 6 Hz.
- EMG signals normalized to average max peak value across all trials
- Data resampled to 100 % of the squat

OpenSim Model and Workflow

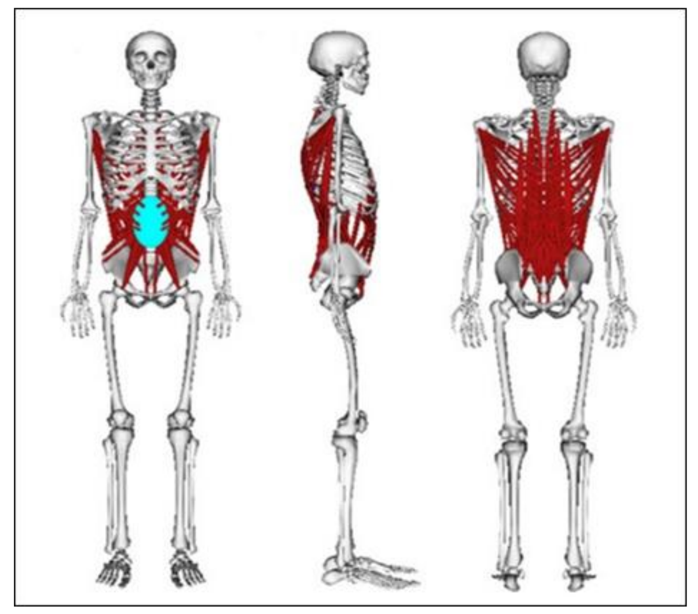

Figure 2: OpenSim Lifting Full-Body Model[3] used to simulate squatting tasks.

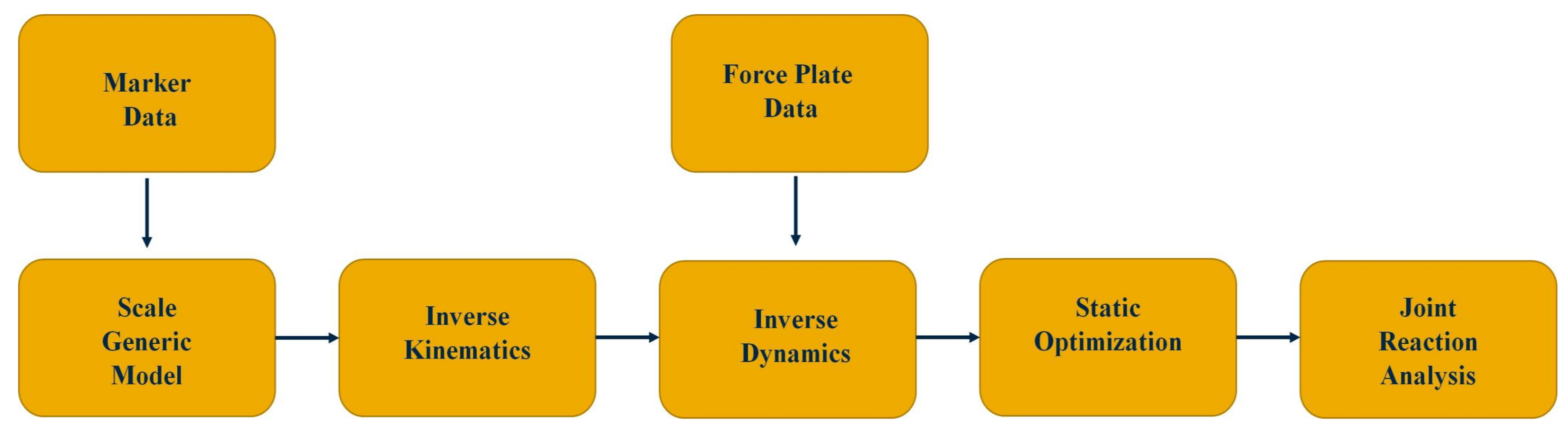

Figure 3: OpenSim workflow, representing all analyses performed, with the exception of joint reaction analysis. EMG data were not inputs to the model and were analyzed separately.

Experimental Results

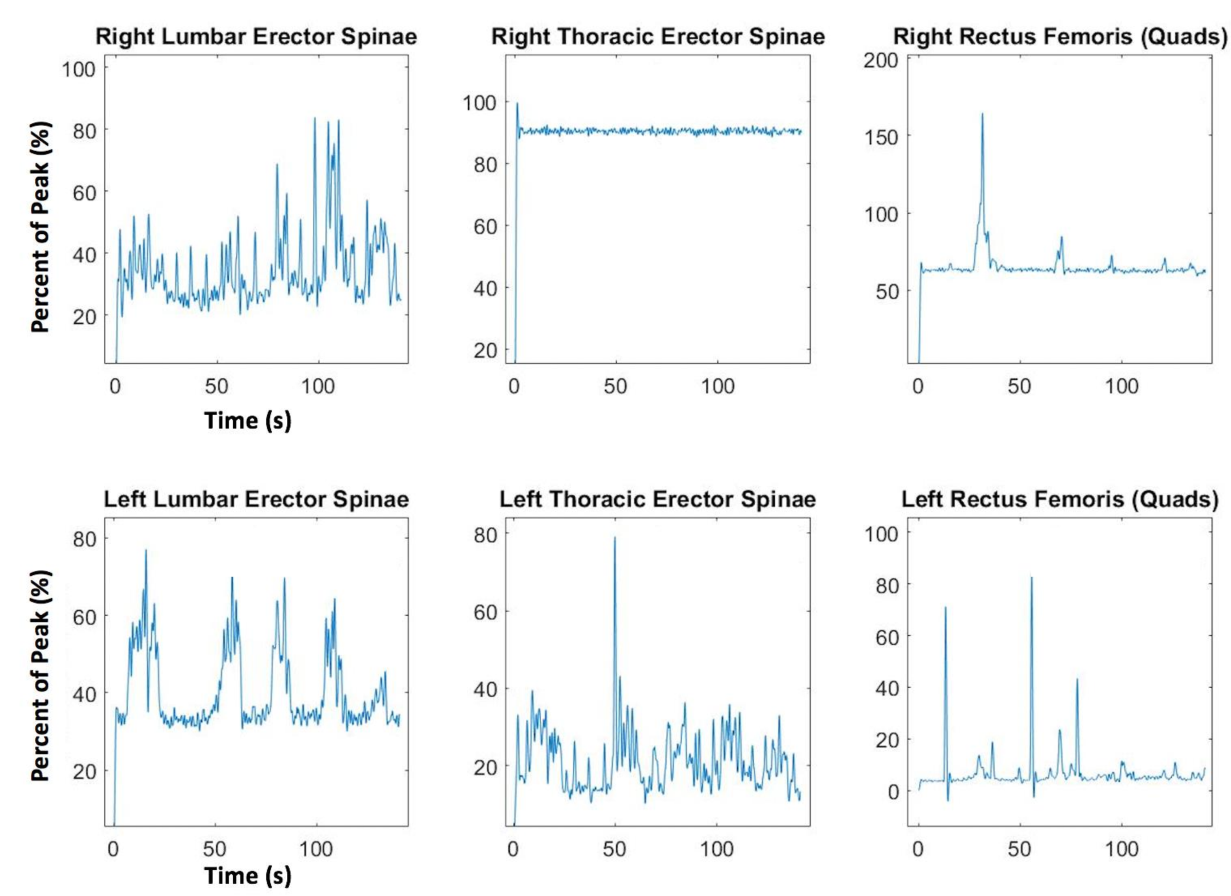

Figure 4: The muscle profiles of the squat tasks in a single trial are shown above. On the top row, the right lumbar erector spinae, right thoracic erector spinae, and right rectus femoris are displayed (left to right). On the bottom row, the left lumbar erector spinae, left thoracic erector spinae, and left rectus femoris are displayed (left to right).

Simulation Results

Contributions of Reserve Actuators at L5/S1 Joint (%)

Flexion-Extension (%)	Lat-Bending (%)	Axial-Rotation (%)
0.0044	6.57e-04	0.0142

Reserve actuators were appended to the L5/S1 joint so that static optimization simulations could converge. Reserve actuator contributions are less than 5%, which suggest that the reserve actuators did not contribute too much to the movement and these results are acceptable[4].

Future Work

- Perform joint reaction analyses
- Compare experimental EMG and simulated muscle activation data to validate the LFB Model
- Collect data with additional subjects and explore additional patient-handling maneuvers (lifting, lowering, twisting, etc.)

Conclusions

Pilot experimental and simulation analyses suggest that the LFB Model may be used to simulate simple squatting tasks. Future work will explore feasibility of the model with additional patient-handling maneuvers. After some modifications to the musculature, the LFB Model may ultimately be used to simulate patient-handling tasks and provide insight on low back loading during these tasks.

References

1.Videman et al. *Spine*, 2005.
2. Seth el al., *PLOS Computational Biology*, 2018.
3. Beaucage-Gauvreau et al. *CMBBE*, 2019.
4. Hicks et al., *J Biomech Eng*, 2015

Acknowledgements

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