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Calibration of OpenSim Lifting Full-Body Model for Dynamic Simulations of Patient-handling Maneuvers

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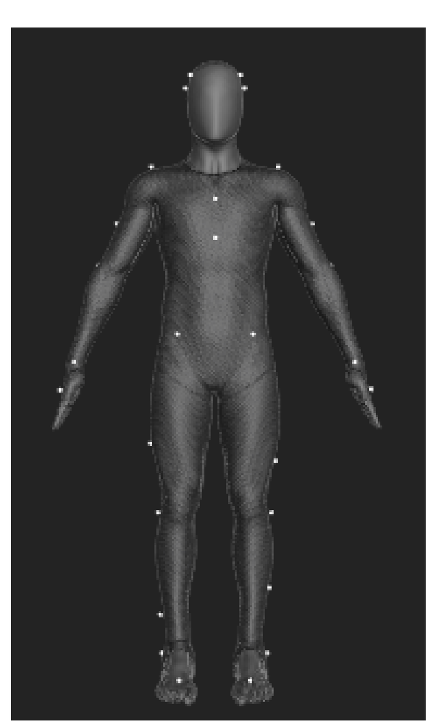
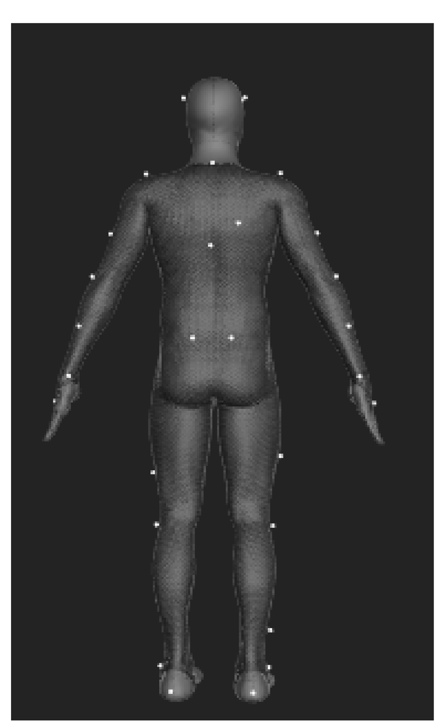
Introduction

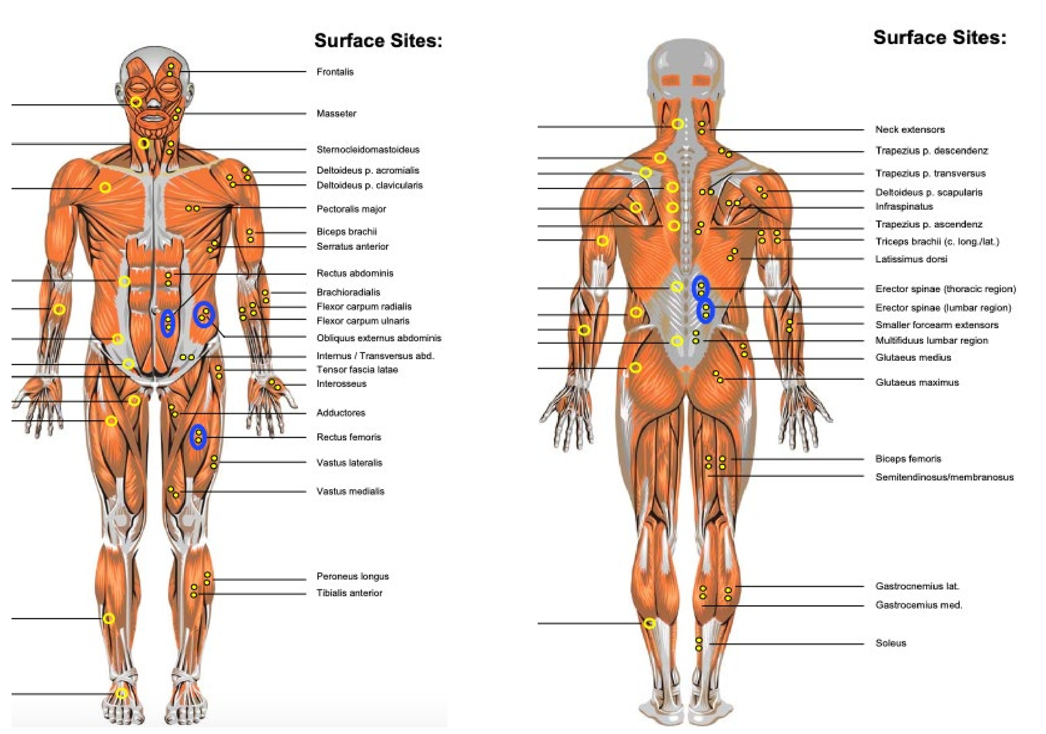
Manual patient-handling tasks may cause lower-back pain and injury for healthcare workers. Computational musculoskeletal models may determine forces on the low back, trunk muscle activation during these tasks, and provide insight on how these may result in injury. These models could be used to develop methods to lower the risk of lower-back pain and injury. OpenSim provides a freely available modeling program. There are many models developed, but none are validated for manual patient-handling tasks. This study aims to develop a calibration procedure to evaluate simulated results and the feasibility of the model.

Methods

- Thirty-nine reflective markers were placed bilaterally on bony prominences for motion capture analysis.
- Ten electromyography (EMG) sensors were attached bilaterally to 5 muscles.
- The subject performed three maneuvers 15 times while standing on two force plates.
  - A twisting motion at the hips, a one arm raise, and a shallow squat.
- Kinematic data were collected at 100Hz, and EMG and force plate data at 1000Hz.
- The kinematic and kinetic data were applied to an OpenSim model to scale and perform inverse kinematics and dynamics.
- The maximum marker error was reported along with the marker locations. The marker locations of the simulation and the raw data were compared using MATLAB code.

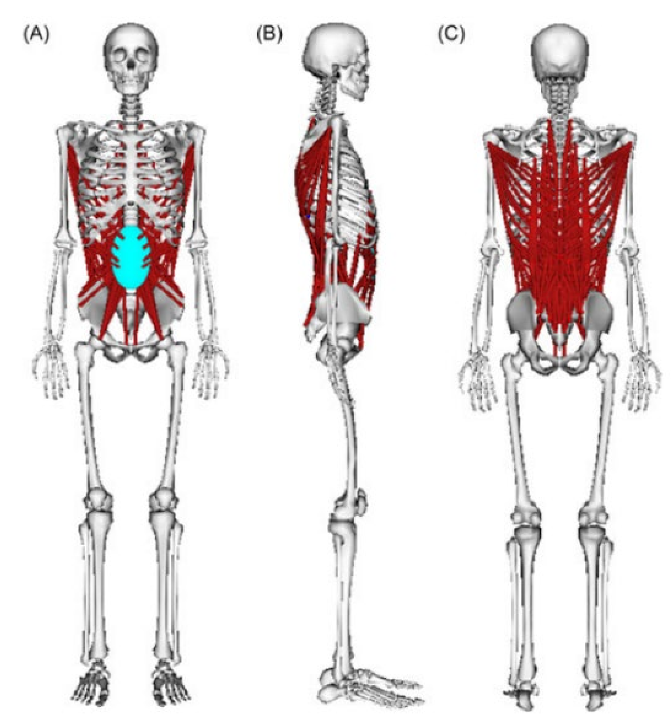
Motion Capture Marker Set



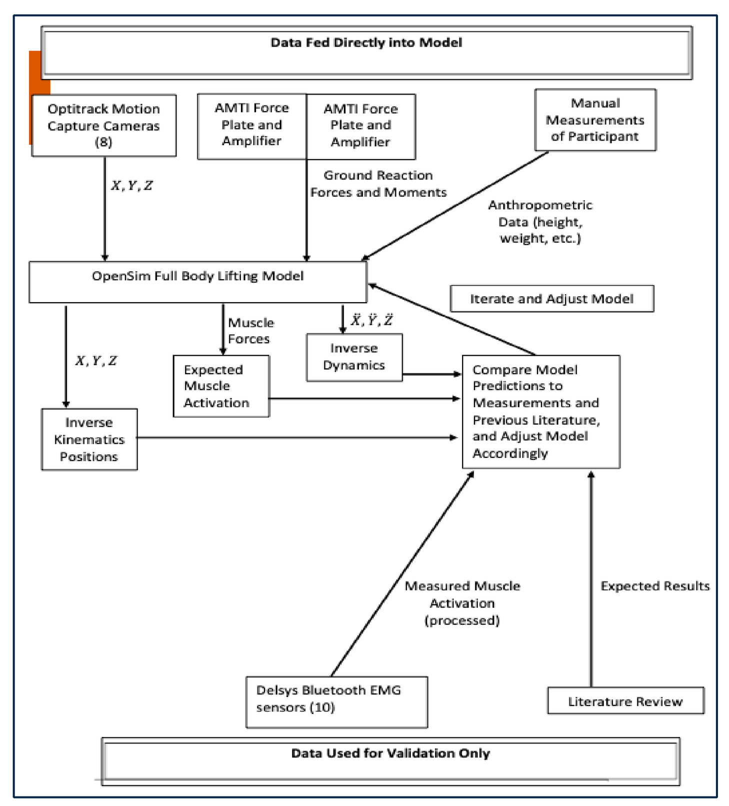
EMG Sensor Placements (in blue)

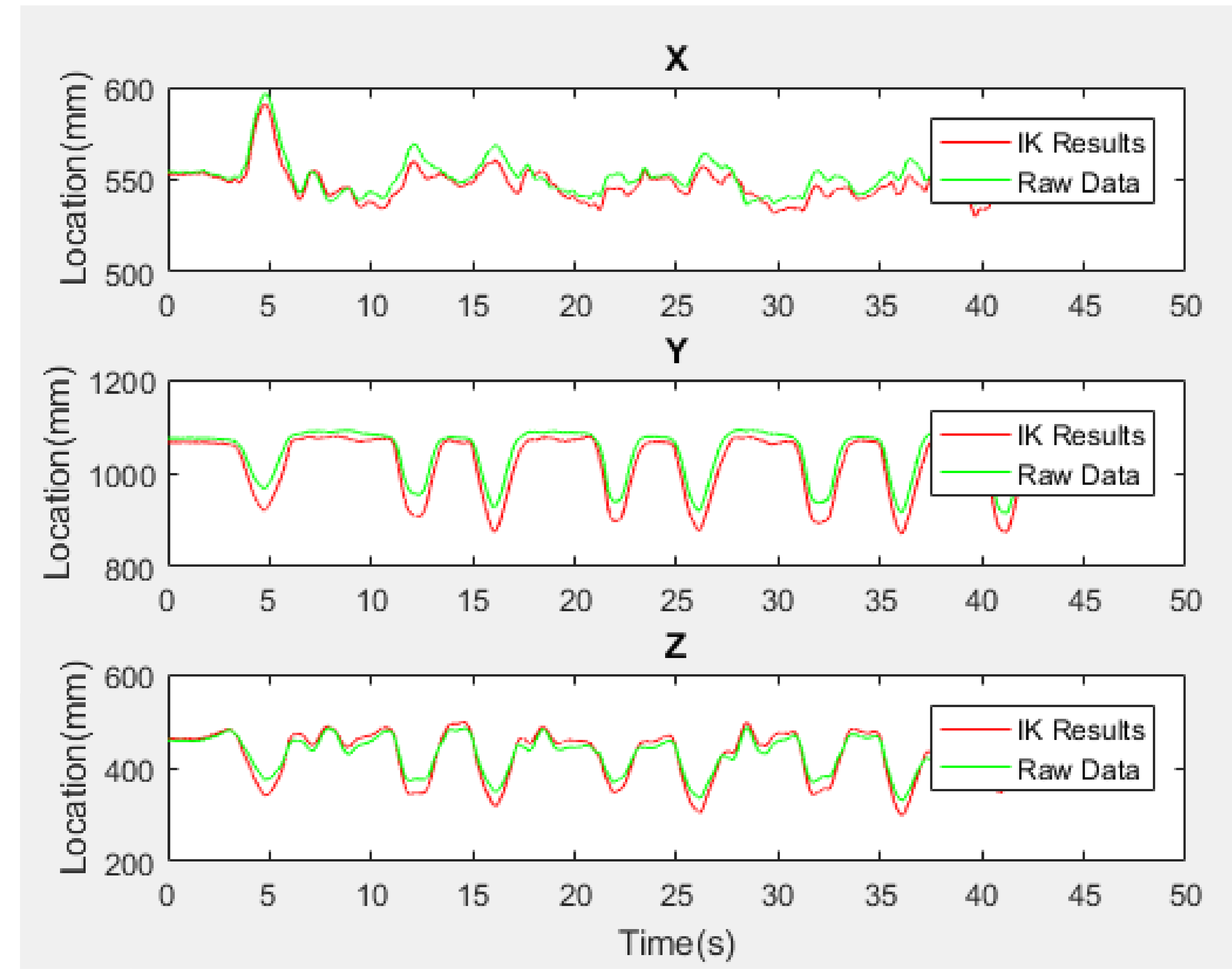
Model

The lifting full-body model with the maker set from the full-body lifting model was used for scaling and inverse kinematics[1,2]. The model has 30 segments, 29 degrees of freedom, and 238 Hill-type musculotendon actuators[1].

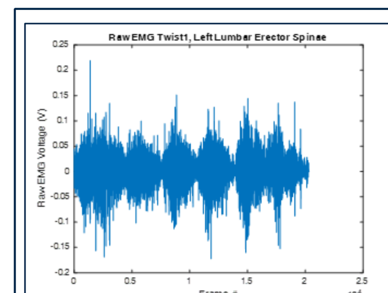


Lifting full-body model with muscle actuators.

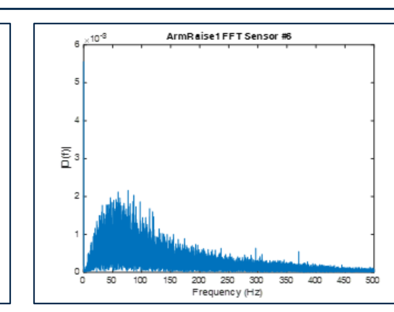




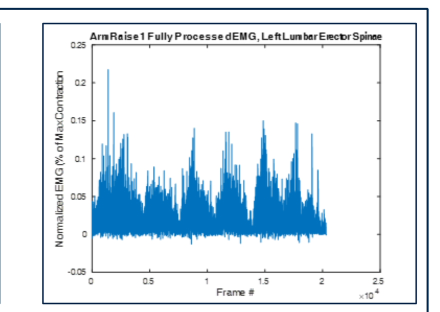
Location of the left anterior superior iliac spine marker.



Raw EMG is fed into MATLAB one muscle/sensor at a time



An FFT is performed to determine the cutoff frequency for a low pass filter



Raw data is rectified, filtered, and normalized to max voluntary contraction, Ready to be compared to modeled muscle activation

	Highest Maximum Error Marker			
	Trial 1	Trial 2	Trial 3	Trial 4
Arm Raise	Left Forehead (13.3cm)	Left Forehead (12.3cm)	Left Forehead (13.1cm)	Right Forehead (10.1cm)
Shallow Squats	Left Forehead (6.3cm)	Right Shoulder (6.4cm)	Left Ankle (7.2cm)	
Twists	Right Shoulder (6.3cm)	Right Shoulder (5.8cm)	Right Shoulder (5.8cm)	

Results

Early modeling results have been used to optimise data collection methods. For example, modeling proved that limiting participant range of motion for specific joints reduces modeling errors from those joints.

It was found that the maximum errors in inverse kinematics were between 1cm and 13cm. Most error was between 1cm and 6cm. Higher errors were found to be in markers that were only needed for scaling, so the error shouldn't affect simulation predictions. To reduce the effect of these markers with high errors, it is possible to reduce their impact on the model by adjusting how much 'weight' that maker has in the calculations.

Conclusions

The range of acceptable marker errors depends on the specific marker. Higher errors on non-essential markers will be ignored, since they will not affect the simulation predictions. For Essential Markers, procedures on marker weighting and limiting subject range of motion will be guided by error analysis of future subject data. After this calibration process is finished, the model will be ready to begin providing reliable information about internal loading of subjects. Data has been collected for three participants, and is now being analyzed.

Acknowledgements

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References

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2. Raabe, Margaret & Chaudhari, Ajit. (2016). An Investigation of Jogging Biomechanics using the Full-Body Lumbar Spine Model: Model Development and Validation. Journal of Biomechanics. 49. 10.1016/j.jbiomech.2016.02.046.