Concurrent OpenSim Model Validation for Loaded and Unloaded Trunk Movements

Matthew P. Mavor[1], Erica Beaucage-Gauvreau[2], Claire F. Jones[2], Stephen H.M. Brown[3], and Ryan B. Graham[1]

INTRODUCTION

- Understanding the mechanics of the spine during activities of daily living and workplace-oriented tasks are important to explain and prevent injury.
- Musculoskeletal models are important tools that have greatly advanced the fields of biomechanics and ergonomics.
  - Allow for a non-invasive approach to *in vivo* type investigations (e.g. muscle function and spinal loads).
- One freely available open-source modelling platform is OpenSim [1].
  - Recently, a full-body lumbar spine (FBLS) model was developed to analyze spinal loads during jogging [2].
- The purpose of this investigation was to validate a modified version of the FBLS model during dynamic trunk movements using a published and validated EMG-driven model [3].

METHODS

PARTICIPANT:

- 1 male with no history of low back pain (21 years; 168 cm; 67.5 kg) was recruited for this study.

PROCEDURE:

- Participant performed a series of loaded and unloaded tasks:
  - One-arm Sweeps: left and right (5 kg)
  - Gait: unloaded, loaded bilaterally (2 x 20 kg), loaded unilaterally (left and right; 20 kg)
  - Lateral Bends: left and right; unloaded, loaded (20 kg)
  - Axial Trunk and Sagittal Range of Motion
  - Quiet Standing: eyes open, eyes closed
  - Standing while Co-contracting (5 seconds)
  - 45 Degrees of Trunk Flexion: loaded 20 kg
  - Box Holds: close to chest, arms extended (20 kg)
  - Set of 5 Squats: ~ 0, 5, 10, 15, 20 kg

EQUIPMENT:

- EMG data collected at 2040 Hz (Trigno, Delsys, USA) bilaterally from 7 key trunk muscles [4].
- Full-body kinematics were collected at 120 Hz through a 10-camera motion capture system (Vantage V5, Vicon, UK).
- Ground reaction force (GRF) data were collected at 2040 Hz by 2 force plates (FP 4060, Bertec, USA).

DATA ANALYSIS:

- Kinematic and GRF data were imported into OpenSim.
  - Calculated joint angles, muscle forces and spinal loads (Figure 1).
- EMG data were processed and normalised to %MVIC [3].
- Lumbar joint angles and net reaction forces from OpenSim, and normalised EMG data were imported into an EMG-driven model to calculate corresponding mean and maximum 3D spine forces [3].

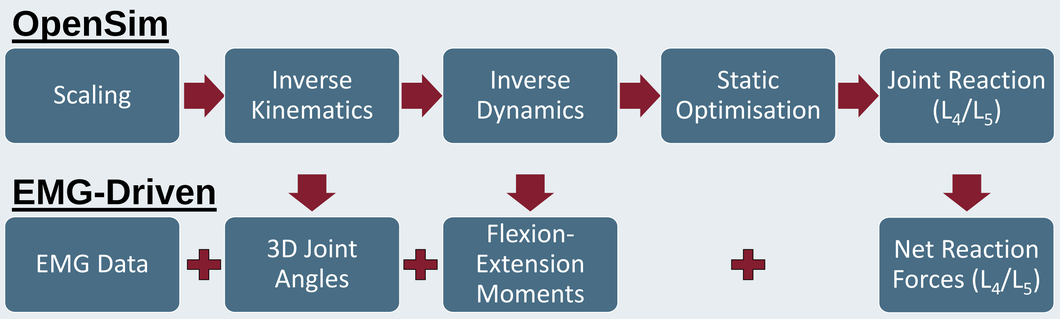

Figure 1. Data analysis inputs to both the OpenSim and EMG-driven models.

RESULTS

- Over all tasks, good agreement was found between the EMG-driven model and the modified FBLS model (Table 1; Figure 2-3).
- ICCs became much stronger with the removal of the co-contraction standing trial (Table 1), for which static optimization and the EMG-driven model were not expected to match.

Table 1. Intraclass correlation results.

Variable	ICC(1,K) All Tasks	ICC(1,K) Removed
Mean Compression	.608	.854
Max Compression	.490	.786
Mean AP Shear	.704	.762
Max AP Shear	.704	.777

Note: The Removed column excludes the standing co-contraction trial. All tasks include every task the participant was asked to perform. In all cases the mean and maximum compression and shear values were taken across the entire movement trial.

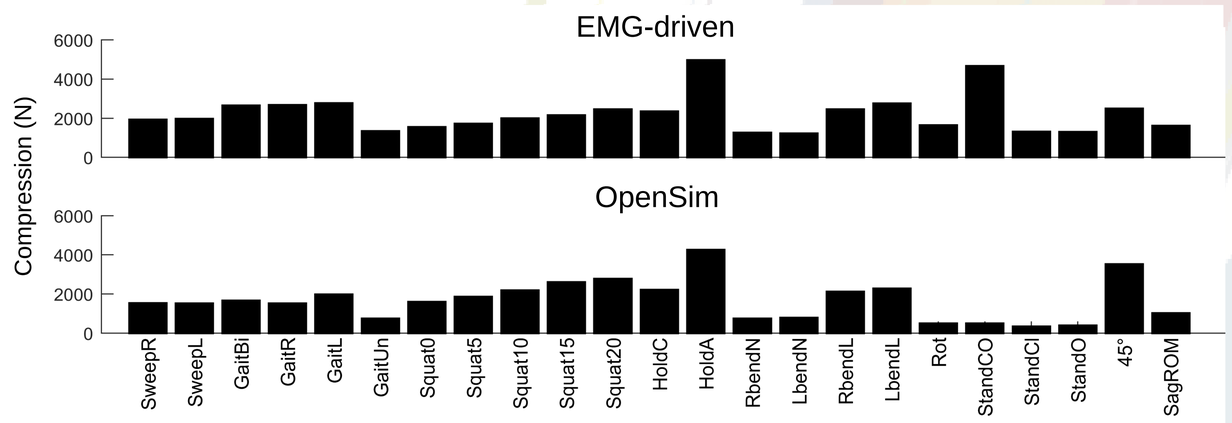

Figure 2. Mean compression results.

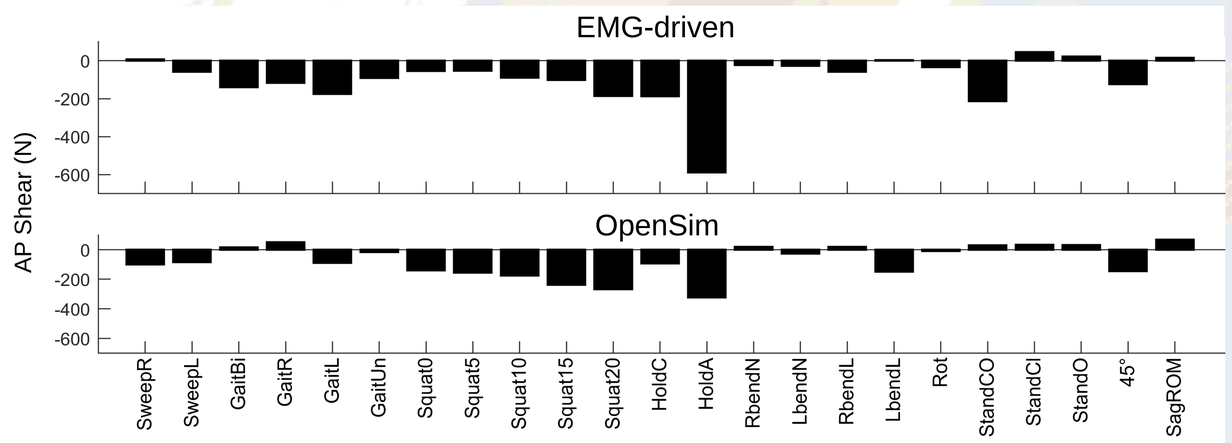

Figure 3. Mean anteroposterior shear results.

DISCUSSION & CONCLUSION

- Working towards a robust model to calculate joint forces and moments is essential to the fields of spine biomechanics and ergonomics.
- The modified FBLS model developed by [2] provides similar outputs to a previously published and validated EMG-driven model [3].
  - This was true in terms of both magnitudes and trends.
- These results instill confidence that this FBLS model is likely an appropriate model to estimate spinal loading during loaded and unloaded dynamic trunk movements.

FUTURE DIRECTIONS:

- Incorporate EMG activation profiles into OpenSim to aid in the accuracy of the model during tasks that involve large amounts of muscular co-contraction.
- Improve methods of prescribing hand loads (i.e. including a box model).

REFERENCES

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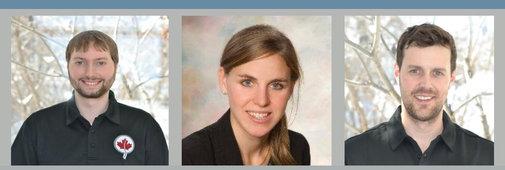

[1]School of Human Kinetics, Faculty of Health Sciences, University of Ottawa
[2]School of Mechanical Engineering and Adelaide Medical School, University of Adelaide, Australia
[3]Department of Human Health and Nutritional Sciences, University of Guelph, Canada

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