**Full-Body Lumbar Spine (FBLS) Model**

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This document is intended to give additional background information and tips for generating simulations with the FBLS model. The FBLS model was created by combining three previously built OpenSim models.[1-3] Please see their respective papers for more information on determination of individual muscle parameters and joint definitions. More in-depth detail on the development and validation of the FBLS model can be found here:

**Raabe, ME & Chaudhari, AMW. An Investigation of Jogging Biomechanics using the Full-Body Lumbar Spine Model: Model Development and Validation. *Journal of Biomechanics*. doi: 10.1016/j.jbiomech.2016.02.046 (2016)**

Please use the above citation when referring to this model.

The model was created and has been used to create dynamic simulations of running gait in OpenSim version 3.2. We have provided some practice data and results so users are able to practice creating simulations with the FBLS model and can check their results against ours. The provided results were also simulated in version 3.2. This model has not been tested in other versions of OpenSim.

**Included files and descriptions:**

| | |
|---|---|
| FBLSmodel.osim | Generic musculoskeletal OpenSim model |
| subject01_Cal01.trc | Static trial collected experimentally |
| SETUP_scale.xml | Setup file for Scale tool |
| subject01_Jog01.trc | Dynamic trial collected experimentally |
| SETUP_IK.xml | Setup file for Inverse Kinematics tool |
| SETUP_RRA.xml | Setup file for Residual Reduction Analysis tool |
| subject01_Jog01_kinetics.mot | Experimental file containing measured external loads (ground reaction forces) from the dynamic trial |
| subject01_Jog01_kinetics.xml | External loads file specifying how to apply the external loads to the model |
| FBLS_RRA_Actuators.xml | Ideal joint actuators used to replace muscles, contains residual actuators |
| FBLS_RRA_Tasks.xml | Tacking tasks file specifying coordinates to track and tracking weight |
| Results cycle01 | Folder with files output from RRA |
| SETUP_SO.xml | Setup file for Static Optimization tool |
| FBLS_SO_Actuators.xml | Actuator file for SO containing the residual and reserve actuators |
| SO Results | Folder containing files output from SO |

**Practice Data Subject Demographics**

| | Sex | Mass | Height | Age | Jogging Speed | Gait Event Timing |
|---|---|---|---|---|---|---|
| **Subject01** | Male | 68.6 kg | 1.7 m | 24 | 2.7 m/s | R FS: t = 0.083<br>R TO: t = 0.38<br>L FS: t = 0.46<br>L TO = 0.75 |

General simulation workflow:

1) Scaling
2) Inverse Kinematics
3) Residual Reduction Algorithm (RRA)
4) Static Optimization (SO)

We used the CFSQP optimizer to generate a solution with RRA, as this optimizer has previously been used to create simulations of running gait in OpenSim.[1] See the following page for a detailed discussion on the different optimizers in OpenSim: http://wiki.simtk.org/opensim/Optimizers. The CFSQP optimizer is not currently distributed with OpenSim, however you can contact AEM at www.aemdesign.com to get a free academic license and then contact the OpenSim team with the license to get the CFSQP dll file. We have regenerated these simulations using OpenSim's default IPOPT optimizer and obtained identical results. The CFSQP optimizer may be most beneficial if generating simulations using Computed Muscle Control rather than SO.

Due to the large number of muscle actuators in the FBLS model, we recommend running SO from the command line to minimize computational cost. To run SO from the command line:

1) Start > Run > cmd > open directory including all SO setup files
2) "Directory to OpenSim bin folder\analyze" –S setupfile.xml

Ex: "C:\OpenSim 3.2 new\bin\analyze" –S SETUP_SO.xml

Additional parameters for each step of the workflow can be found in their respective settings files. Please refer to OpenSim User's Guide for more information on each tool and best practices used in creating simulations.

**Note: FBLS model is not yet suited for CMC.** Changes were made to the maximum isometric force (Fmax) properties of some muscles (described here[4]) in order to make muscles strong enough for jogging in healthy young adults. Since the passive forces in muscles are modeled as a function of Fmax, this results in unrealistically high passive muscle forces in the model. SO is not affected by this since it does not take passive muscle properties into account, however CMC does. Future research will investigate this issue in order to make the model suitable for CMC.

**References**


1. Hamner S, Seth A, Delp S. Muscle contributions to propulsion and support during running. *J Biomech* 2010;43:2709-16.
2. Christophy M, NA FS, Lotz J, et al. A musculoskeletal model for the lumbar spine. *Biomechanics and modeling in mechanobiology* 2012;11:19-34.
3. Arnold EM, Ward SR, Lieber RL, et al. A model of the lower limb for analysis of human movement. *Annals of biomedical engineering* 2010;38:269-79.
4. Raabe ME, Chaudhari AMW. An Investigation of Jogging Biomechanics using the Full-Body Lumbar Spine Model: Model Development and Validation. *Journal of Biomechanics* 2016. doi: 10.1016/j.jbiomech.2016.02.046