

London Lower Limb Model

The details of the London Lower Limb Model are contained in the publication:

Modenese, L., Phillips, A.T.M., Bull, A.M.J., *An open source lower limb model: Hip joint validation*, J Biomech, in press, doi:10.1016/j.biomech.2011.06.019

Please cite this publication when using the model or a modified version of the model.

1 Details and references

The following points describe some details and report references used in implementing the London Lower Limb Model:

- Muscle attachments, joint kinematics (patella included) and muscle contraction parameters are based on the anatomical dataset published in Klein Horsman M.D. et al., *Morphological muscle and joint parameters for musculoskeletal modelling of the lower extremity*, Clin Biomech, 22:239-247, 2007.
- The ISB anatomical coordinate systems are adopted in the model. Wu G., et al. *ISB recommendation on definitions of joint coordinate system of various joints for the reporting of human joint motion--part I: ankle, hip, and spine*, J Biomech, 35:543-548, 2002. The origin of the pelvis reference system has been moved to the midpoint between the two hip joint centres.
- In the original dataset the insertion of the muscle Adductor magnus (dist) is located in the Tibia. This is anatomically incorrect (Gray, H., *Anatomy of the Human Body*, Philadelphia: Lea and Febiger, 1918) and the insertion was moved to the femur.
- In the original dataset the rest position of the foot is rotated externally in an unnatural way. A rest position coincident with the ISB reference position was hence adopted for the foot. Because of this choice, the talocrural joint axis in the foot is slightly different from the original one, while the axis on the tibia is unchanged. It is possible to use the original joint axis by modifying the orientation of the segment 'Hind_Foot' with the values available in the comment on the talocrural joint.
- A cylindrical wrapping surface representing the anterior femoral condyles was introduced in the model to match experimental measurements of the quadriceps moment arm (Buford, W.L. et al., *Muscle balance at the knee--moment arms for the normal knee and the ACL-minus knee*, IEEE Trans Rehabil Eng, 5:367-379, 1997). The bundles of the quadriceps are affected for knee flexion angles higher than about 90 degrees.
- Joint range of motion was limited using the values published in Boone, D. C. and Azen, S. P. *Normal range of motion of joints in male subjects*, JBJS (Am), 61:756-759, 1979.

2 Limitations of the model

The model presents some known limitations:

- The model has been implemented and used in OpenSim 1.9. Please report any compatibility problem encountered in using it with more recent versions of OpenSim.
- This model is supposed to be used only for static optimization analysis. In addition, as described in the associated publication, simulations were run without considering the force-length-velocity relation. **CMC simulations cannot be run at this stage of development of the model.**
- Implementing the muscle attachments reported in the Klein Horsman dataset, the superior bundles of *gluteus maximus* appear to cross the *gluteus medius* bundles. Appropriate wrapping surfaces will be introduced in a future release of the model in order to preserve the layered structure of the gluteal muscles.
- Some insertions of the *gluteus maximus* bundles are located cranially with respect to the hip joint center. This may be a consequence of the choice, in the Klein Horsman dataset, to consider as insertion for the superior part of the muscle the ilio-tibial band.
- The bone geometry of the specimen that the original muscle data were collected from by Klein Horsman et al. was not available to the developers of this model. Therefore, the bone files included in the model are taken from the Geometry folder available in the OpenSim distribution and manually fitted to the muscle attachments. Although their role is purely cosmetic, a future release of the model will improve this aspect of the model.

3 How to use the model

1. Copy the obj files included in the 'Bones' folder to the OpenSim Geometry folder.
2. Load the model from the GUI.
3. Bony landmarks as measured by Klein Horsman et al. can be added to the model from the included xml file or by uncommenting the appropriate section of the osim file.
4. Ligaments as measured by Klein Horsman et al. are also included in the model as commented muscles in the osim file.

Please report any problem or suggestion to: I.modenese08@imperial.ac.uk

**https://simtk.org/home/low_limb_london
www.imperial.ac.uk/structuralbiomechanics**