

APPENDIX B: KINETIC MODELING DETAILS

The Visual3D model defined the joint center locations using the standing calibration trial marker positions. The hip joint center was 25% of the distance from the ipsilateral greater trochanter to the contralateral greater trochanter (Weinhandl & O'Connor, 2010). The knee joint center was the midpoint between femoral epicondyles, and the ankle joint center was the midpoint between the malleoli. Segment inertial parameters were calculated using regression equations from Dempster (1955) and the Hanavan (1964) model.

Resultant joint kinetics were calculated using a recursive inverse dynamics scheme. The body segments were “unlinked”, and a resultant force and moment were defined at each end of the free segment. The Newton-Euler equations of motion for any segment were:

$$\sum \bar{F} = \frac{d}{dt} m\bar{v} = m\bar{a} \quad (\text{Eq. B1})$$

$$\sum \bar{\tau} = \frac{d}{dt} \mathbf{I}\bar{\omega} = \mathbf{I}\bar{\alpha} + \bar{\omega} \times (\mathbf{I}\bar{\omega}) \quad (\text{Eq. B2})$$

where \bar{F} and $\bar{\tau}$ are general forces and moments acting somewhere on the segment, \bar{v} and \bar{a} are the linear velocity and acceleration of the segment's center of mass, $\bar{\omega}$ and $\bar{\alpha}$ are the segment's angular velocity and acceleration, m is the mass of the segment, and \mathbf{I} is the inertia tensor for moments of inertia about the segment's center of mass

By expanding the left-hand side of Eq. B1, the equation for the resultant force \bar{F}_R at any joint in an open chain of segments is:

$$\bar{F}_R = \sum_{i=1}^s m_i (\bar{a}_i - \bar{g}) - \bar{F}_{GRF} \quad (\text{Eq. B3})$$

where m_i is the mass of the i^{th} segment distal to the joint, \bar{a}_i is the center-of-mass acceleration of that segment, \bar{g} is the gravitational acceleration, and \bar{F}_{GRF} is the GRF. From Eq. B2, the resultant moment $\bar{\tau}_R$ at the same joint is:

$$\bar{\tau}_R = \sum_{i=1}^s [\bar{\tau}_i^I + \bar{r}_i \times m_i (\bar{a}_i - \bar{g})] - \bar{\tau}_{GRF} - (\bar{r}_{GRF} \times \bar{F}_{GRF}) \quad (\text{Eq. B4})$$

where \bar{r}_i is the vector from the joint to the center of mass of the i^{th} distal segment, \bar{r}_{GRF} is the vector from the joint to the center of pressure, and $\bar{\tau}_{GRF}$ is the ground reaction moment. $\bar{\tau}_i^I$ is the inertial moment of the i^{th} distal segment. Equation B4 calculates $\bar{\tau}_R$ in the global (lab) reference frame. Results were then expressed in the LCS of the distal segment.

REFERENCES

- Dempster WT. Space requirements for the seated operator. In: *Wright Air Development Center Technical Report* (pp. 55-159). Dayton: Wright-Patterson Air Force Base, 1955.
- Hanavan EP. A mathematical model for the human body. *Army Med Res Lab Tech Rep.* 1964;64-102:1-149.
- Weinhandl JT, O'Connor KM. Assessment of a greater trochanter-based method of locating the hip joint center. *J Biomech.* 2010;43:2633-6.