ESTIMATION OF MIDFOOT AND ANKLE KINETICS DURING WALKING

Philippe C. Dixon, Harald Böhm
Orthopaedic Hospital for Children, Behandlungszentrum Aschau GmbH
email: phil.dixon@mail.mcgill.ca

INTRODUCTION
The foot is a complex structure comprised of several independent functional units [1]. Increasingly, multi-segment foot models are being used in both clinical and research settings to more closely approximate intra-foot segment kinematics and drive clinical decision making [2, 3]. However, the analysis of intra-segment kinetics are less common [4].

The Oxford Foot model (OFM) [2] is a multi-segment representation of the foot available as a plugin for the Vicon Nexus software package (Vicon, Oxford Metrics, UK). This model represents the foot as three independent rigid segments: The hallux, the forefoot and the hindfoot and computes three-dimensional intra-segment kinematics. No kinetic data are provided, however as with the Plugin-gait model (PIG) (Vicon, Oxford Metrics, UK), segment embedded axes defined by virtual markers contained in the model output files can be used in conjunction with force plate data to compute intra-foot segment dynamics [5].

The aim of this study was to implement a kinetic analysis of the midfoot and ankle using the OFM and to compare ankle kinetics computed via the OFM and PIG. Further, clinical importance is demonstrated through sample data from a pathological subject with equinus gait.

METHODS
Seven adolescents (6 females, 1 males, 15.6 ± 1.1 years, 162.7 ± 10.0 cm, and 56.4 ± 8.0kg) performed barefoot walking trials at a self-selected comfortable walking speed. Reflective markers were positioned along anatomical landmarks according to the PIG and OFM. Marker data were collected and processed using the Vicon Nexus software (Vicon, Oxford), while force plate data were acquired via 2 AMTI (AMTI, Watertown, MA, USA) force plates embedded within the walkway.

Data were imported into Matlab® (v2006b, The Mathworks Inc., Natwick, MA, USA) where segment embedded axes were extracted from the processed PIG virtual marker data and used to compute ankle kinetics using a standard Newtonian inverse dynamics approach [5]. This method was then modified to include segment embedded axes within the forefoot and hindfoot from the OFM virtual markers. Finally, work near foot-off were computed by taking the time integral of the power generation curve.

RESULTS AND DISCUSSION
For the group of seven subjects, the ankle generation power and work near foot-off estimated using the OFM was approximately 40% less than the values computed via the PIG methods (Fig.1, Table 1).

Using the OFM, the midfoot power generation was 0.32 W/kg while the work was 0.16 J/kg (Fig.2, Table 1).

Figure 1: Ankle power during stance estimated via the OFM and PIG.

Figure 2: Midfoot ankle power during stance estimated via the OFM.
For the subject walking with equinus gait, ankle OFM power absorption near foot-strike and power generation near foot-off were reduced compared to the PIG (Fig. 3).

![Figure 3: Ankle power during stance computed using the OFM and PIG for a subject walking with equinus gait.](image)

The contribution of the midfoot to power absorption near foot-strike and power generation near foot-off are also presented (Fig. 4).

![Figure 4: Midfoot power generation during stance for subject walking with equinus gait.](image)

Kinetic data for the seven subjects are similar to normative data reported by other authors [6,7]. Additionally, the OFM model reveals non-negligible midfoot generation power and work near foot-off. These kinetic quantities are the result of the foot musculature and can now be separated from the gastrocnemius activity.

For the subject with equinus gait, midfoot kinetics reveal important clues to the stresses placed within the foot during gait and could help in the prevention of midfoot break.

By modeling the foot as a single rigid segment, the ankle generation power and work near toe-off and the ankle absorption and work at foot-strike are overestimated. The individual contributions of the forefoot and hindfoot musculature are masked and included in the overall results.

**CONCLUSIONS**

Treating the foot as a single rigid segment considerably overestimates the power contribution of the ankle joint through inverse dynamic analysis during gait. Considerations about storage and release of triceps surae energy might therefore be overestimated in previous calculations. Therefore, we strongly recommend to use a two segment foot model, specifically in children with Cerebral Palsy where surgery on the triceps surae muscle is based on 3D gait analysis.

**REFERENCES**


**Table 1:** Ankle and midfoot power (W/kg) and work (J/kg) near foot-off calculated by OFM and PIG.

<table>
<thead>
<tr>
<th></th>
<th>OFM</th>
<th>PIG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midfoot Power (W/kg)</td>
<td>0.32 (0.15)</td>
<td>-</td>
</tr>
<tr>
<td>Ankle Power (W/kg)</td>
<td>2.10 (0.98)</td>
<td>3.69 (1.12)</td>
</tr>
<tr>
<td>Midfoot Work (J/kg)</td>
<td>0.02 (0.01)</td>
<td>-</td>
</tr>
<tr>
<td>Ankle work (J/kg)</td>
<td>0.16 (0.07)</td>
<td>0.28 (0.09)</td>
</tr>
</tbody>
</table>