Kinetic Assessment of the Shoulder during Lofstrand, Crutch-Assisted Gait in Children with Myelomeningocele (MM)

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Introduction: Myelomeningocele (MM) is a complex disease that often results in functional disability. Studies have shown that approximately 50% of children with MM ambulate in the community; 23% of these use assistive devices (Lofstrand crutches) [1]. During crutch-assisted gait, peak axial loads on the upper extremity (UE) are substantial. Literature has shown that long term crutch usage, may result in UE pathologies, such as destructive shoulder arthropathy, degenerative arthritis of the shoulder and wrist joints, and/or carpal tunnel syndrome [2-4].

Currently, only limited models exist for quantitative assessment of UE dynamics in children with MM. Dynamics of the lower extremities during crutch-assisted gait have been studied in children with MM using three-dimensional (3D) motion analysis [5]. However, movements of the UEs during gait have only been investigated to a small extent in children with MM [6]. Therefore, a 3D biomechanical model of the UEs was developed for dynamic analysis of Lofstrand crutch-assisted gait in children with MM.

This research study investigates two common types of gait patterns used by children with MM: 1) reciprocal gait and 2) swing-through gait. We hope to gain a better understanding of the demands placed on the UE joints during these gait patterns. Investigation of the forces exerted on the shoulder will be helpful in understanding loading patterns and ambulatory control associated with the respective crutch-assisted walking patterns. We also hope to determine if gait pattern alterations may serve as an injury prevention strategy.

Materials and Methods: The UE model is composed of 2 crutch segments and 7 rigid-body segments: right/left crutch, thorax, right/left upper arm, right/left forearm, and right/left hand. Twenty-six passive reflective markers were used to define the segments. The model design was based on previous work and recommendations by the International Society of Biomechanics (ISB) [7, 8]. Lofstrand crutches were instrumented with customized six-axis AMTI transducers to measure applied reaction forces and moments. UE dynamics were captured using a Vicon MX system. Kinematic and transducer force data were then combined in an inverse dynamics solution to determine shoulder joint kinetics.

Nine subjects with MM participated in a gait analysis at Shriners Hospital for Children, Chicago. The mean age of participants was 11 ± 4 years. All subjects had an L3 or L4 level myelodysplasia and were able to walk with crutches in both reciprocal and swing-through patterns. Subjects walked with instrumented Lofstrand crutches at a self-selected speed until 5 successful trials were completed for each gait pattern. Mean peak shoulder forces and moments during reciprocal and swing-through gait were compared using the Wilcoxon signrank test (alpha = 0.05).

Results: Shoulder forces during swing-through gait were far greater than those during reciprocal gait. The superior/inferior shoulder forces were found to be the highest among the three planes of motion. The largest joint forces were directed inferiorty. At both shoulders, the inferior shoulder force was found to be significantly different between reciprocal gait and swing-through gait. The left shoulder superior force was found to be significantly different between gait patterns. Right and left shoulder joint forces presented similar morphology during both gait patterns.

The maximum flexion/extension moments were found to be similar during reciprocal and swing-through gait. Right and left joint moment morpologies were similar. Maximum Shoulder Forces and Moments

<table>
<thead>
<tr>
<th>Gait Pattern</th>
<th>Right Shoulder</th>
<th>Left Shoulder</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flexion (+) / Extension (-)</td>
<td>Flexion (+) / Extension (-)</td>
</tr>
<tr>
<td>Reciprocal Gait</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Swing Through Gait</td>
<td>0.5</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Discussion: Analysis of shoulder joint forces showed that the largest forces were directed inferiorly (compression) with maximum forces occurring during swing-through gait. Concern arises regarding the magnitude of these UE forces because high glenohumeral forces have been identified as a source of shoulder pain and pathology. It has also been shown that bearing weight through the upper limbs may hasten the development of other upper limb pathologies, such as carpal tunnel syndrome. Therefore, further kinetic analysis is underway to determine joint forces and moments placed on the wrist and elbow during crutch-assisted gait in the MM population. Knowledge from the studies may prove useful for developing injury prevention strategies and improving rehabilitation protocols. Ultimately, we may prescribe a specific gait pattern for a subject based on mobility needs, walking strategy and an injury prevention paradigm.


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