INTRODUCTION

- Motor vehicle collisions (MVC), especially those of side impact, are a leading cause of injuries and death among children.¹
- During side impact MVCs, the positions of the occupant’s head, neck, and thorax heavily depend on the biomechanical response of the shoulder.²
- Therefore, having a more biofidelic shoulder in pediatric anthropomorphic testing devices (ATD) is essential to accurately simulate the occupant’s response to side impact MVCs and design better safety measures.
- The objectives of this study are: 1) determine the pediatric shoulder’s resistance to medial and posteromedial loading conditions and 2) compare shoulder resistance by age groups.

MATERIALS & METHODS

- Previous testing protocol was modified and applied, using VICON optical motion capture, electromyography (EMG), and resistive loading.³
- A total of 39 pediatric volunteers between 4-18 years old (Table 1) were tested. This age range was selected to represent the 6 year old, 10 year old, and 5th percentile female ATDs.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-7 years old</td>
<td>8</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>8-12 years old</td>
<td>8</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>13-15 years old</td>
<td>2</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 1. Volunteer Statistics

- A custom linear force applicator (Figure 1) was utilized to displace the shoulder and measure the applied forces. The applicator’s design enabled translational motions in all directions to ensure proper alignment and to allow loads to be applied in both medial and posteromedial directions.
- The subjects were seated against a support wall, equipped with load cells, in order to limit rotation and translation of the subject and to determine the amount of load translated by the subject’s upper torso.
- An 8-camera 100 Hz VICON motion analysis system was used to measure shoulder and thoracic displacement. Reflective markers were taped to the skin over the subject’s acromion process of both scapulas, manubrium of the sternum, and lateral epicondyle of the right humerus (Figure 2).
- For each volunteer, the loading apparatus was placed to the subject’s right and the load arm was manually applied (Figure 3). A total of 16 tests were performed per subject: 5 with the subject’s muscles relaxed, followed by 3 while tensed, for both medial and posteromedial loading directions.

RESULTS & DISCUSSION

- Medial testing resulted with minimal shoulder displacement at these low loads due to the clavicle acting as a strut and supporting the shoulder girdle. Due to the limited displacements, medial stiffness could not be calculated for the age groups.
- The posteromedial force-displacement data from all trials for each volunteer were averaged to calculate a mean stiffness curve for each subject (Figure 4). The mean curves from all volunteers in an age group were then averaged to calculate a mean curve and standard deviation for each age group. This process was completed for both relaxed and tensed loading conditions (Figure 4).
- Shoulder stiffness, k, was then calculated by taking the slope of each age group’s mean curve in order to compare shoulder resistance to loading across all age groups and loading conditions (Table 2).

CONCLUSIONS

- Medial stiffness could not be calculated due to limited measured displacement.
- Shoulder stiffness increases with age and also with muscle tension for the posteromedial loading direction.
- Posteromedial shoulder stiffness should be taken into consideration when designing new pediatric ATDs, to ensure a biofidelic response.

Table 2. Posteromedial Stiffness Values

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Stiffness (N/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relaxed</td>
<td>Tensed</td>
</tr>
<tr>
<td>4-7 years old</td>
<td>1.57</td>
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<tr>
<td>8-12 years old</td>
<td>2.26</td>
</tr>
<tr>
<td>13-18 years old</td>
<td>3.48</td>
</tr>
</tbody>
</table>

References


Acknowledgements

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