Pediatric Shoulder Response to Lateral and Posteroomedial Loading

Jane Lee1, Brian Suntay2, Austin Meek3, John H Bolte IV4

1College of Medicine, The Ohio State University; 2Transportation Research Center, Inc.; 3College of Medicine, The University of Cincinnati; 4Biomedical Informatics, The Ohio State University

INTRODUCTION

• Minor vehicle collisions (MVCs), especially those of side impact, are a leading cause of injuries and death among children. During side-impact collisions, the position of head, neck, and thorax heavily depend on the biomechanical response of the shoulder. Therefore, having a more biofidelic shoulder in thorax heavily depend on the biomechanical response of the shoulder.

• This project sought to (1) determine the pediatric shoulder’s response to lateral and posteroomedial loading conditions and (2) characterize the stiffness ratio of the pediatric shoulder.

• The research hypothesis was that the Pediatric shoulder stiffness should be characterized by determining the lateral and posteroomedial stiffnesses of the shoulder in order to accurately simulate side impact MVCs and design better safety systems. At this time, however, pediatric ATDs have been constructed primarily from tissue properties and scaled-down extension of adults and animal simulations despite the differences in development and physical characteristics.

MATERIALS & METHODS

Subject Selection

With full IRB review and approval, this study tested 39 pediatric volunteers between 4-18 years old (Table 1). The age range was selected to represent the 4-7 year old, 8-12 year old, and 13-18 percentile female ATDs. There were no weight or height requirements for the exclusion criteria was any history of injury or magical interference to the elective, suprascapular, or scapular

Equipment

• A custom linear force applicator designed by Suntay (Figure 1) was utilized to display the shoulder and measure the forces required to do this. The applicator contains a load cell for measuring the load transmitted through the limb and a platform for proper alignment with the subject’s right, leading shoulder. The direction in which it attaches also affects both lateral and posteroomedial loading directions. A 220-N capacity load cell from Transducer Techniques (Model DSM-50).

• A walk-in loadcell structure was built on the left side of the unit, consisting of a few removable plates mounted to a vertical bracket. Each plate was equipped with a load cell. Together, these measured the impact transmitted through the left shoulder and arm, while the end structure was a walk-up subject and a ground-based structure.

• To determine the stiffness ratio, first an effective stiffness (keff) for each subject and test condition was calculated using Equation 3.

RESULTS & DISCUSSION

INTRODUCTION

• In general, shoulder stiffness in lateral direction is considerably greater than in posterioromedial direction because the clavicle acts to restrict the lateral movement of the shoulder. On the other hand, stiffness in posteroomedial direction is less because the clavicle rotates posteriorly and allows the scapula to slide along the scapulohumeral joint.

• Shoulder stiffness should be identified by characterizing both lateral and posteroomedial directions. In lateral direction, the stiffness of 4-7 years old group is 1.4 times the stiffness of 8-12 year old group and the stiffness of 13-18 year old group is 1.8 times the stiffness of 8-12 year old group. In posteroomedial direction, the stiffness of 4-7 year old group is 2.6 times the stiffness of 8-12 year old group.

• Bony structure likely explains the increase in stiffness with age. The data show that the shoulder stiffness is more complex and not transmitted through the scapula and thoracic joint.

• Both lateral and posteroomedial loading conditions were performed for each subject.

• The stiffness of the pediatric shoulder was measured in detail due to limitations in testing itself. It was a challenge to combustion for the side of testing motion to younger pediatric subjects. Without the exception of minimum or maximum testing during the baseline MVCs, testing it was not analyzed the tested loading mode. Furthermore, especially in younger subjects, testing often had an unwanted motion of the scapula and body. This study affected the measured displacements.

CONCLUSIONS

• The pediatric shoulder stiffness increases with age in both lateral and posteroomedial loading directions. This is due to increasing musculoskeletal bony structures as well as some contribution of soft tissue development. Lateral and posteroomedial shoulder stiffness should be taken into consideration when designing the side-impact ATDs for the testing of side impacts. Further testing will be beneficial in increasing the statistical significances of the data.

Data Reduction & Analysis – I don’t really understand the ‘a’ can some really tough to explain.

• Data from subjects age 13 to 18 were not standardized to the anthropometry of a 10% percentile data, data from subjects age 8 to 12 were normalized to the anthropometry of the 10 year old ATD. Data from subjects age 4 to 7 were normalized to the anthropometry of the 4 year old ATD. Normalization in bone density was based on young mean values, following (Nisha, 1984), which incorporated the response data into the determination of the stiffness ratio.

• To determine the stiffness, first an effective stiffness (keff) for each subject and test condition was calculated using Equation 3. Then a percent error ratio (%) was calculated by dividing the subject’s effective stiffness by their shoulder’s, where the shoulder’s stiffness was determined the most appropriate characteristic length for this study. Within each test condition the values (%) were averaged across subjects (Mean %) and finally the stiffness ratio (SR) was calculated using Equation 3.

• Table 2: Age and Gender Breakdown of Subjects

RESULTS & DISCUSSION

Instrumentation

• An inhouse 9080 VICON motion analysis system was used to measure the shoulder and thoracic displacements. Reflective markers were placed on the skin over the subject’s acromion process of both scapulas, manubrium of the sternum, and lateral epicondyle of the humerus (Figure 2).

• For EMG, measuring the muscle activity during the tests, surface electrodes were applied to the key muscles involved in shoulder movement and stability: latissimus dorsi, trapezius, deltoid, biceps brachii, and pectoralis major muscles.

• The shoulder apparatus and the bench were located at the center of the VICON motion capture field. Each subject was seated on the bench, supported by a seatback and the load-cell wall on the left, with the right shoulder free to move (Figure 3).

• Before positioning the loading arm, maximum voluntary contractions of the muscles were determined using EMG. Reflective markers were placed on the subject’s right and left shoulder, right and left elbow, right and left shoulder, and right and left hand. On completion, the loading apparatus was placed on the subject’s right with the right arm adjusted and centered at the lateral part of the deltopectoral groove covering the scapular process. The horizontal placement of the load cell wall was also adjusted so that the subject was seated with the spine on the edge of the outward while their left foot and arm were touching the wall.

• For each test, the load arm was manually pushed by the researcher and displaced the subject’s shoulder. Total motions were performed per subject. For each subject’s muscles relaxed, followed by another three trials, in both lateral and posteroomedial loading directions.

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• The pediatric shoulder stiffness increases with age in both lateral and posteroomedial loading directions. Due to increasing musculoskeletal bony structures as well as some contribution of soft tissue development. Lateral and posteroomedial shoulder stiffness should be taken into consideration when designing the side-impact ATDs for the testing of side impacts. Further testing will be beneficial in increasing the statistical significances of the data.