Introduction

Motor vehicle crashes, especially side impacts, are a leading cause of death and disability to the pediatric population as they account for approximately 50% of pediatric trauma [1]. Sixteen percent of children were non-fatally injured while 32% of children have died as a result of vehicle side impacts [2]. According to the Crash Injury Research Engineering Network (CIREN), children involved in side impact crashes are more likely to suffer severe injuries to the head and thorax [1]. The placement of the head and thorax during impact has been shown to be heavily dependent on the response of the shoulder mechanism [3].

Due to the need to increase safety in automobiles, the automotive industry has been actively researching methods to prevent injury during car accidents. Potential improvements must first be tested to verify that they reduce injury. This is done through the use of anthropomorphic test devices (ATDs), which provide a method for analyzing the injuries involved in a vehicle crash [1]. However, the data used to design pediatric ATDs is derived and scaled from adults and animal surrogates and it is uncertain whether they are accurate for the child population [4]. In addition, the dynamic response of the pediatric shoulder, which plays an important role in the response of the head and neck during impact, has not been researched and modeled into pediatric ATDs.

Objectives

- Perform quasi-static, noninvasive shoulder displacements on adult volunteers to define the adult shoulder’s stiffness
- Perform quasi-static shoulder stiffness testing and dynamic, noninvasive impacts on adult post mortem human subjects
- Perform quasi-static shoulder stiffness testing on pediatric volunteers
- Define a correlation between quasi-static and dynamic stiffnesses and find the pediatric shoulder’s response to dynamic loading conditions

Methods

The right shoulders of six adult volunteers were quasi-statically displaced in four directions: medially, anteromedially, posteromedially, and inferiorly. A combination of motion testing using a point-cluster technique to measure 6-degree-of-freedom motion of the shoulder; resistive loading using a load cell to measure the shoulder’s resistance to quasi-static loading; and electromyography (EMG) recordings to measure the activation of the shoulder muscles during loading was utilized.

In each subject, reflective markers were placed on the upper right arm, both acromions, the manubrium, and the medial and lateral epicondyles of the right elbow. Surrogates were applied to the latissimus dorsi, upper trapezius, anterior and posterior deltoids, biceps brachii, and pectoralis major. The right shoulders of each subject were quasi-statically displaced using a handheld force applicator. A load cell attached to the applicator recorded the forces during the motion while an 8-camera Vicon motion capture system tracked and recorded the shoulder’s motion. During the test, electrodes measured the activity of the shoulder muscles during loading.

Results and Discussion

The response of each subject’s shoulders appear to follow a similar pattern. The force-displacement curves of the shoulders appear to be almost linear and there is little variation in the stiffness of each subject’s shoulder, with the exception of subject 6. The interior loading condition data for subjects 4-6 has not yet been processed. An abnormal curve was observed in subject 4’s lateral data and was omitted. The abnormality of the curve’s shape might be due to an error in the tracking of the reflective markers.

Conclusion

The method for quasi-statically and noninvasively measuring the force-displacement characteristics of the shoulder seems promising. However, more subjects need to be tested before moving on to pediatric subjects.

References


Figure 1. Force applicator and guide that can be adjusted to the four desired directions.
Figure 2. Electrode placement: latissimus, trapezius, deltoid, biceps, pectoralis.
Table 1. Stiffnesses (N/mm) for the subjects’ shoulders calculated as the slope of the linear fit to the force-displacement curves. Stiffnesses were calculated for the shoulders for each of the loading conditions.