Comparison of Q3s ATD Biomechanical Responses to Pediatric Volunteers

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Abstract

The biofidelity of pediatric ATDs continues to be evaluated primarily in comparison to scaled down adult data. The viability of this approach is questionable as it assumes that the anatomical, anthropometric, and biomechanical differences between adults and children are negligible. This assumption has been shown to be invalid in many cases. Thus, it is important that pediatric ATDs be evaluated by comparison to human pediatric data and not solely scaled down adult data. In this study, we aimed to evaluate the biomechanical responses of the Q3s ATD, a 3 year-old ATD developed specifically for side impact testing, using pediatric volunteer data. The purpose of this project was to quantitatively compare biomechanical responses of certain aspects of the new Q3s side impact ATD with those of pediatric volunteers.

We replicated 2 studies with the Q3s ATD that were previously conducted with pediatric volunteers to capture pediatric biomechanical responses and properties for lateral and oblique loadings. In these experiments we evaluated (1) shoulder biofidelity using quasi-static conditions and (2) overall kinematic biofidelity using low speed far-side sled tests. For the quasi-static shoulder tests, force-deflection curves were obtained by applying force to the right shoulder with a load cell and measuring shoulder displacement using a 100 Hz 3D motion capture system. The sled tests, designed using an amusement bumper-car impact, were conducted with a 2g sled acceleration and a 54 ms rise time. Kinematic responses including lateral displacement of the torso, torso rollout angle projected onto the coronal plane, and torso rollout angle projected onto the transverse place, were calculated by tracking photoreflective targets with a 100 Hz 3D motion capture system. Previously obtained volunteer data were used from studies conducted by Suntay, et al. (2011) and Arbogast, et al. (2012) and included 14 subject ages 4-7 years old and 7 subjects ages 6-8 years old, respectively.

The Q3s shoulder exhibited higher stiffness values (36.2±5.35 N/mm) than the volunteers in both relaxed (2.8±1.3 N/mm) and tensed (3.5±2.1 N/mm) muscle conditions. Q3s kinematics curves analyzed for low speed far-side sled tests, however, were qualitatively similar to those of the volunteers. Q3s peak values were within one standard deviation of the lateral torso displacement volunteer values in lateral trials (202.4±33.0 mm, Q3s: 194.6 mm) and of the transverse rollout angle values in lateral (42.7±10.2°, Q3s: 45.4°) and oblique (37.9±10.8°, Q3s: 45.9°) trials. While overall volunteer and Q3s kinematic trajectories were similar, the mechanism by which they achieved this trajectory appeared different. Specifically, the Q3s seemed to show more head rotation while the volunteers exhibited more spine translation.